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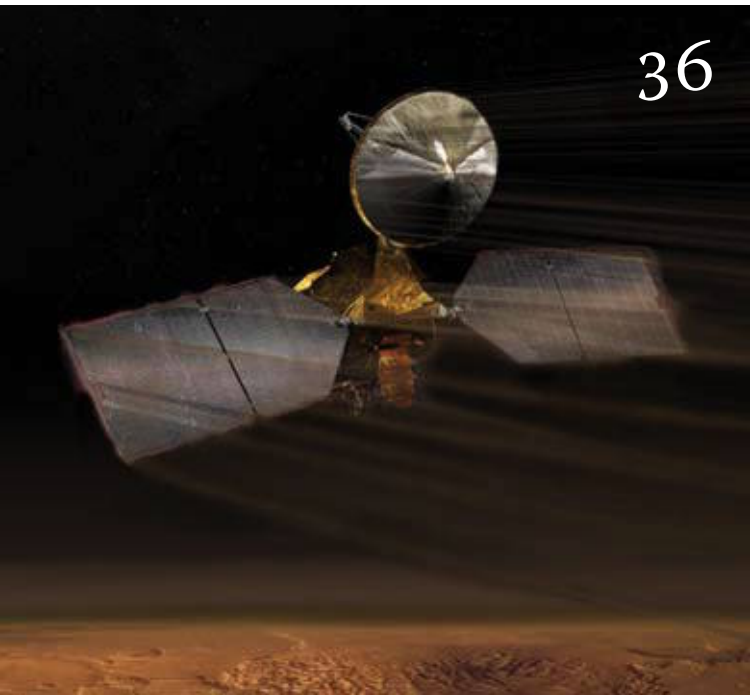

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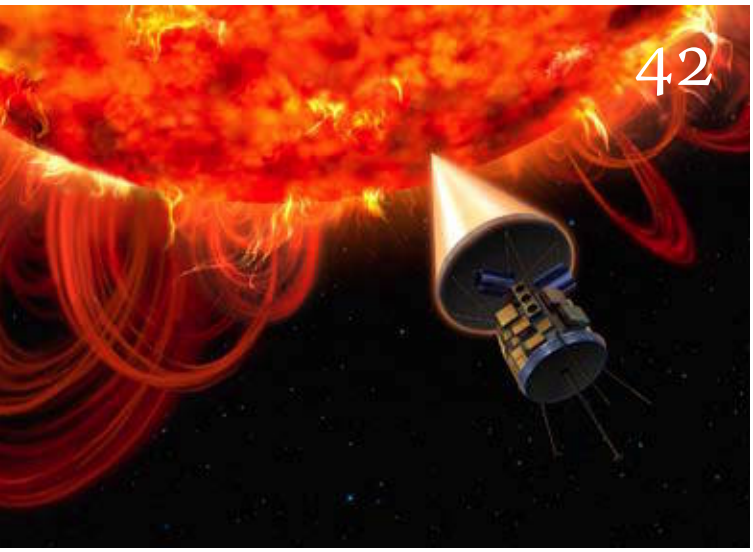

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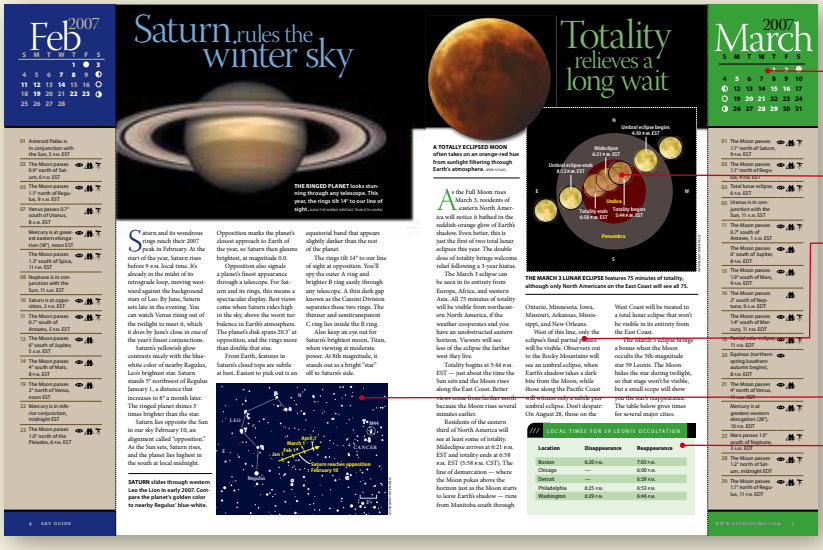
Feb 2007
Saturn rules the winter sky
THE RINGED PLANET looks stunning through any telescope. This year, the rings tilt 14° to our line of sight.
A TOTALLY ECLIPSED MOON often takes on an orange-red hue from sunlight filtering through Earth's atmosphere.
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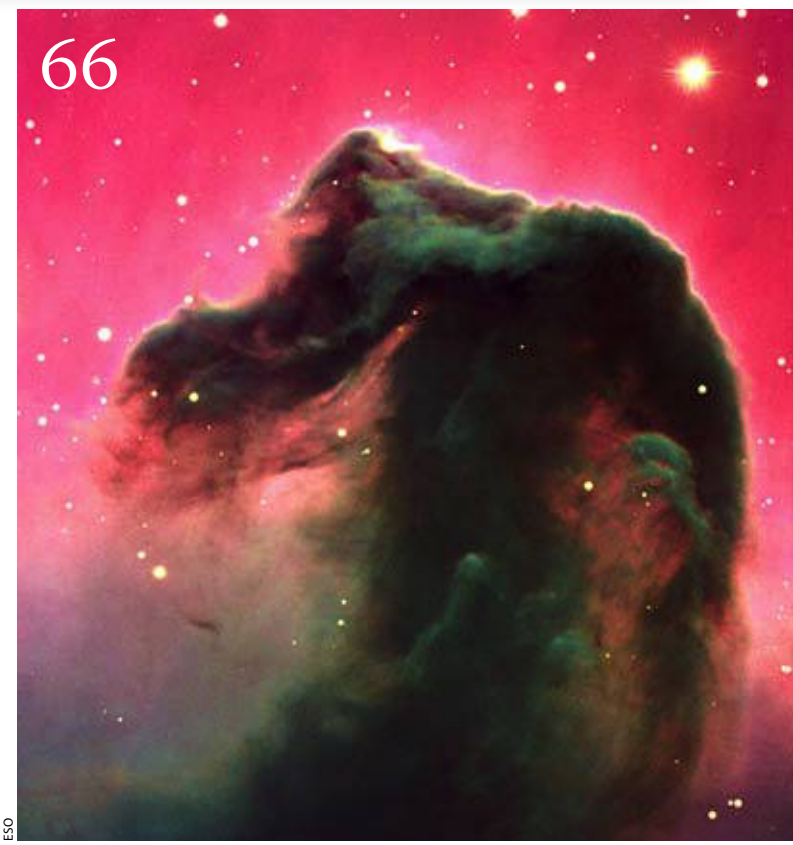

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BY DAVID J. EICHER

Down to 8

In August, the International Astronomical Union (IAU) stunned the world. For the first time in 76 years, Pluto was front-page news. This time, it wasn't only in newspapers: It was a lead story on the world's leading news channels and web sites. Meeting in Prague, Czech Republic,

the IAU demoted Pluto. No longer termed a planet, Pluto became merely a dwarf planet, in the same category as minor planets Eris and Ceres. Why now, after 76 years of planethood? Legions of schoolchildren lost their collective temper. And they weren't the only ones.

In "Pluto gets the boot" (page 78), Associate Editor Francis Reddy explains Pluto's demotion. "It was Caltech astronomer Michael Brown's January 2005 discovery of Eris — formerly known as 2003 UB_{313} — that created the urgent need for a definition," writes Reddy. The IAU committee charged with defining what constitutes a planet could only agree to disagree by late 2005. Astronomers presented a new resolution at the IAU meeting in August 2006. At first, they floated the notion of keeping Pluto as a planet and also promoting Eris and Ceres. By this definition, dozens of objects in the solar system would need to be dubbed planets. The situation seemed to be spiraling out of control.

So the IAU drew up a new proposal and voted it through into "law." The governing body created a new class of solar system objects — dwarf planets — and made Pluto one of them. So Pluto, after 76 years, lost its planetary citizenship.

In *Astronomy*'s exclusive podcast (download it at www.astronomy.com/podcasts), Brown tells Assistant Editor Jeremy McGovern: "Ever since the first Kuiper Belt object was discovered in 1992, it was known that Pluto was not alone out there … but it was always something that could be swept under the rug." He is satisfied with the outcome, deeming it "the right scientific choice."

Not all astronomers back this decision, however. Alan Stern, principal investigator of the New Horizons mission that is en route to Pluto, strongly condemns the resolution. "I'm not happy with it because it's a sloppy definition," says Stern in the same podcast. "If you read it verbatim, it says that an object has to orbit a star, has to be big enough to make itself round by gravity, and I like that, but then it says it has to have cleared its zone. Well, that's the problem, because Earth hasn't cleared its zone, where there are thousands of near-Earth asteroids, and Jupiter hasn't cleared its zone, because of the jovian Trojans, 100,000 of them. … If it were a research paper, it would never have passed refereeing."

Pluto's discoverer, Clyde Tombaugh, died in 1997. What would he have thought? His widow, Patricia, also spoke with McGovern. "Clyde would have said, 'It's there, so there it is!' … He would understand that as we get better equipment with our studies, we get better information, and it hasn't changed his status," she explains. "It's rather disturbing, after 75 years as a major planet," that the change came.

A petition now circulates among planetary scientists, many of whom say they will ignore the IAU resolution. The struggle over Pluto's citizenship, it seems, will go on.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 34, Number 12

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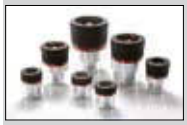

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Some rare meteorites found close to home

Thanks for your special meteorite issue

(August 2006). Bill Cooke's "The great interplanetary rock swap" states that Heat Shield Rock found by the Mars rover Opportunity is "the first meteorite of any type identified on another planet." This assertion is also made on NASA's web site; however, it's incorrect. Two milligram-size meteorite fragments have been identified in regolith samples from the Moon: Bench Crater, a CM1 chondrite picked up by Apollo 12 astronauts in 1969; and Hadley Rille, an EH chondrite collected by Apollo 15 astronauts in 1971. Although Heat Shield Rock appears to be a common type of iron meteorite, the lunar meteorites are of unusual types. — **ALEX RUZICKA,** DIRECTOR, CASCADIA METEORITE LABORATORY, PORTLAND STATE UNIVERSITY, PORTLAND, OREGON

Indeed — I recently learned meteorites exist in the lunar archive at the Johnson Space Center. They're rare finds close to home. — **BILL COOKE,** NASA/MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

Getting in the groove of things

In "Name that rock" (August 2006), one detail caught my eye. The chart on how different types of meteorites are classified says iron hexahedrites have Widmanstätten bands greater than 50mm. All of the other classifications range from 0.2mm to 3.3mm. I am no meteorite expert, but from what I can see, it is a simple typo where a decimal has been left out. — **DAVID BARRY,** ST. LOUIS, MISSOURI

ROBERT HAAG

WIDMANSTÄTTEN lines on iron meteorites can range in size from just 0.2mm to greater than 50mm.

Actually, that's not a typo. Hexahedrites have no discernible Widmanstätten bands. What that really means is the bands are extremely wide — more than 2 inches (50mm). So when cut and etched, they don't show the pattern characteristic of other iron meteorites. They do exhibit a fine set of parallel lines called Neumann lines, after the fellow who first described them. Neumann lines measure on the order of a few microns wide, so they're not readily apparent, except through a microscope. — **MICHAEL E. BAKICH,** SENIOR EDITOR

A striking difference

While reading "Intelligent Life In the Universe" by I. S. Shklovskii and Carl Sagan (1966) and looking at the images of celestial objects in black and white (from Mt. Wilson and Palomar observatories), I realized how good the astroimages are today in "Reader gallery" — especially when you consider the aperture difference between amateurs' and observatories' telescopes. The quality difference is amazing! — **KEITH SOEHN,** REGINA, SASKATCHEWAN

Correction

In "Tales from the dark side" (September 2006), the quote, "We are incredibly lucky to be working just at the moment when the pieces of the cosmic jigsaw puzzle are falling into place," was attributed to Sean Carroll instead of Robert Kirshner. — ***ASTRONOMY* EDITORS**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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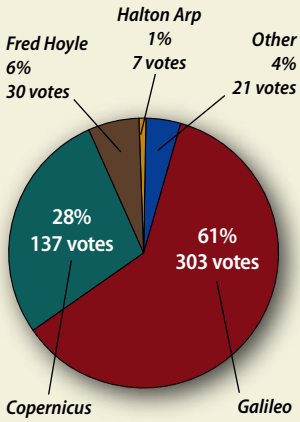

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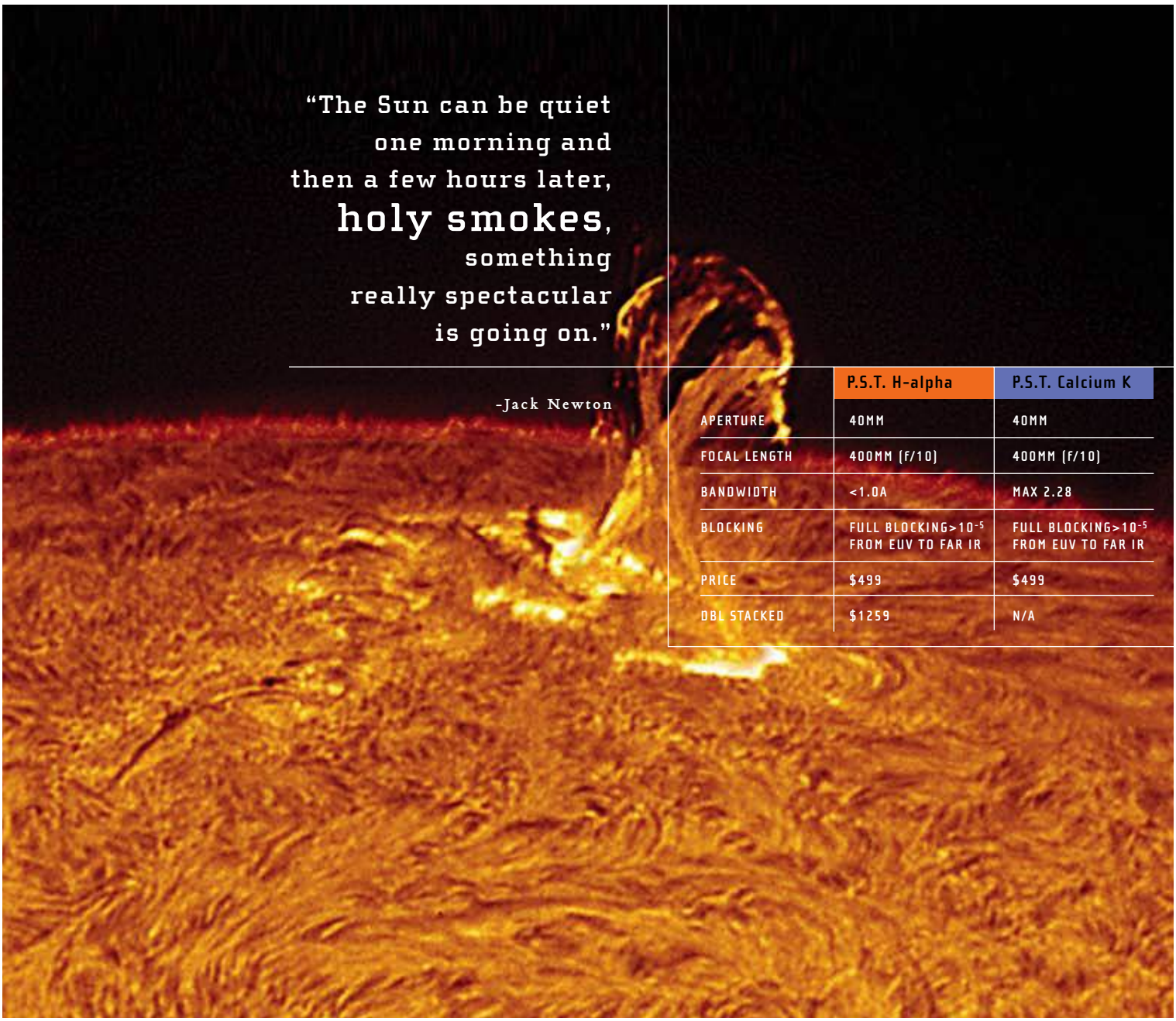

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Dr. Steven Pollock (Ph.D., Stanford University) is Associate Professor of Physics at the University of Colorado at Boulder. He received the Boulder Faculty Assembly Teaching Excellence Award in 1998. He became a Pew/Carnegie National Teaching Scholar in 2001.

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BY BOB BERMAN

Goodbye, Pluto

As we all know, the International

Astronomical Union (IAU) gave Pluto the boot. What amazes me is how many people care deeply about it. Some are actually depressed. They grew up with Pluto, and now it's been demoted to a dwarf, like many other Disney characters.

Fortunately, the IAU waited until after 1997, when Clyde Tombaugh died. The final-planet discoverer went to his grave happy, even though he was still around when we started to understand just how "Goofy" the ninth world really is.

Me, I like the IAU decision. As a guest on the *Late Show with David Letterman* a few years ago, I'd grandly announced that Pluto wasn't really a planet. The initial pro-planet decision by an IAU committee last August would have made me wrong.

The final IAU edict produced additional consequences. For example, Ceres is now promoted from asteroid to dwarf planet, simply because it's roundish. But they're not fooling anyone. We know it's still an asteroid.

Charon, Pluto's main moon, was briefly a planet, too, for about a week before astronomers laughed it out of the room. Now it's back to being just one of the solar system's 140-odd moons.

The IAU's initial criteria for planethood included a clause that in two-body systems, the smaller object must orbit a spot outside the surface of the first.

Throughout the universe, nothing strictly goes around anything else. Rather, every pair of objects performs a waltz around the place in space where their gravities balance. With Pluto-Charon, that spot lies outside Pluto's surface. Our moon, although 4 times the size of Charon, was denied planet status because the Earth-Moon balancing point lies under Earth's surface, ⅛ of the way to our core.

But catch this: The Moon's leaving us at 1.5 inches (38mm) a year. So someday, the spot it orbits will float outside our surface. At that moment, according to the IAU's first definition, it would have suddenly become a planet. No wonder they abandoned the whole thing. It was too complicated.

No one admitted this, but there was an unspoken ingredient in the deliberations. The word "planet" has a special place in our hearts because we live on one. We tacitly want our world to be part of a special club, and that's been true up until now. Even second-graders know all the planets' names. Each planet is famous. So, in a way, the IAU needed a membership criterion that would keep out the riffraff. Any society that includes a Jupiter and a Saturn shouldn't grant membership to an icy piece of garbage smaller than our moon. Otherwise, there goes the neighborhood.

> I'M SURPRISED THAT the blood lust of battle didn't inspire the IAU to hack away at other celestial objects.

Then there was the matter of tradition. Pluto almost made it on those grounds because it's been in our brains all our lives. The problem was, if you let in Pluto, you open the door to all those tiny Kuiper Belt low lifes. Pretty soon you'll have 15 planets, then 40, and they'll have weird names, and nobody will remember them all, and ...

Well, it didn't happen.

I'm surprised that the blood lust of battle didn't inspire the IAU to hack away at other celestial objects. Why stop at Pluto? Why not trim away all the annoying designations in the entire universe?

Like the constellations Cancer (horrible), Virgo (gets giggles), and Musca (a fly). Who decided to glorify a pest? Keep Musca, and you might as well gaze up at Virella the Virus. Golden Retriever — there's a creature that belongs in the heavens. Norma, Antlia, Scutum (sounds like sputum), and a dozen others should have been edited out centuries ago. They may have tradition, but has anybody ever said, "Come outside, honey, let me point out Scutum!"

While you're at it, rename all stars with six or more syllables: Zebeneschamali, for instance, whose name means "claw" even though it's part of Libra. Scales shouldn't have claws, except in nightmares.

And christen more galaxies. Right now, only about a dozen have official names, while billions more suffer the indignity of license-plate letters and numbers.

They can leave everything else. All those two-word color terms are fine. Black hole, brown dwarf, red giant, green flash, blue shift, white dwarf. Nice and catchy. Distance terms are fabulous, too: parsec, light-year, and astronomical unit. They sound cool.

Actually, come to think of it, the whole science has a pretty fine nomenclature system. Astronomy may be "out there" for most people, but its language is wonderfully intriguing, and most of its celestial bodies sound just the way they should: exotic and alluring.

So — barring further changes by planetary astronomers who hate this whole thing — we'll simply get used to "dwarf planet." Sorry, Pluto, but you had to see it coming.

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IMAGINOVA

BY GLENN CHAPLE

Get into observing

"What's a good beginner's telescope?"

I often hear this question at star parties and from readers of this column. The person asking is either a newbie eager to buy a scope for personal use or someone who wants to purchase one for a friend or relative bitten by the astronomy bug.

The galaxy of instruments available on the market overwhelms many first-time buyers. If you're one of them, sit down and relax while I fill you in on the ins and outs of purchasing a good beginner's scope.

First, a bit of advice you probably won't want to hear: "Before you buy, know the sky." It's easy to understand why someone who just saw a fascinating astronomy show on television would want to pick up a telescope and blast off into space. Alas, the voyage will be short-lived if the viewer can't identify key stars and constellations.

FOR BINOCULAR OBSERVING, *Astronomy*'s "The sky this month" and Chet Raymo's *365 Starry Nights* can prepare you before heading outside, and serve as guides while you're skywatching.

ASTRONOMY: WILLIAM ZUBACK

I speak from experience. After being introduced to the sky by my second-grade teacher, I couldn't wait to see firsthand the cosmic wonders she described in class. A "telescope" fashioned from a milk carton with a slit at one end where I inserted crayon drawings of the planets and viewed through a hole at the other end didn't satisfy my cosmic wanderlust. So I did what any kid would do — held my breath, whined, and begged until my parents gave in and bought me a small tabletop refractor.

At first, my heavenly odyssey went well. The Moon was a fabulous sight in my small scope. But when I ventured to other parts of the galaxy and couldn't find my way, I became discouraged and bored. Eventually, my poor little telescope was relegated to the toy box, where it met an untimely demise under my Tonka trucks.

A telescope in the hands of someone who doesn't know his or her way around the night sky is doomed to a similar fate — well, maybe not in a toy box, but certainly the attic or cellar. Search Amazon.com for Chet Raymo's *365 Starry Nights*. This book takes the reader on night-by-night tours into the cosmos. Through clear illustrations and text, Raymo explains how to find the constellations and then describes the wonders contained therein.

As for the goings-on of the Moon and planets, that's where the current issue of *Astronomy* comes in. "The sky this month" (page 48) is a handy guide to the naked-eye sights that greet you when you step outside at night. With Raymo's book and a current issue of *Astronomy*, anyone can navigate the night sky like a pro.

A second pre-telescope must is good binoculars, preferably the 7x50 or 10x50 size. Binoculars bridge the gap between unaided eye and telescope and really come into their own on large, bright sky objects like the Pleiades or Andromeda Galaxy. The number preceding the "x" is the magnifying power; the number following is the diameter of the objective lenses, expressed in millimeters. Every experienced amateur astronomer I know owns and regularly uses binoculars. The good news for the beginner is that, if he or she doesn't already own binoculars, it's fine to purchase a pair right away and use them while learning the night sky. Take the time to explore some of the binocular sights that my friend Phil Harrington describes in his column (page 20).

And now to answer the question, "What's a good beginner's telescope?" For me, nothing is a better fit for the novice than a Dobsonian-mounted reflector — a 4-inch for a youngster or slight-of-build adult, a 6-inch for anyone else. Such an instrument is a versatile performer — allowing views of the Moon, planets, and hundreds of deep-space objects.

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FOR NEXT MONTH: Can you guess what this object is? JOHN RUMMEL

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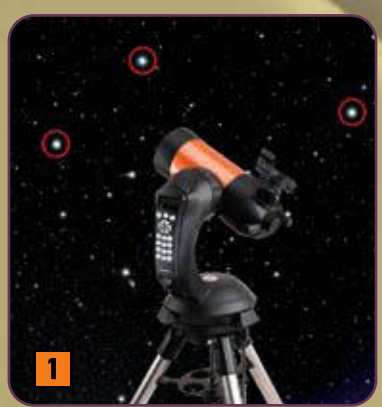

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BY PHIL HARRINGTON

A celestial bull ride

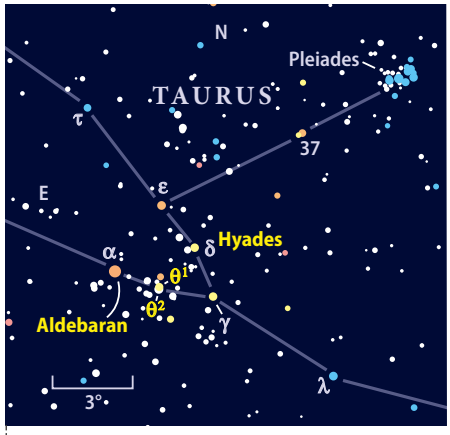
Although winter doesn't begin until 12:22 A.M. Universal Time on December 22 (7:22 P.M. Eastern Standard Time on December 21), its imminent arrival is signaled weeks before as the season's brilliant constellations begin to join our eastern sky. To me, winter starts

when I first see Taurus the Bull rising above the leafless trees in the evening, chased by Orion the Hunter and his entourage.

The bright orange star **Aldebaran**, which marks the bull's eye, dominates Taurus. The rest of Taurus' head is outlined by a V-shape pattern of fainter stars called the **Hyades**. In ancient Greek, "hyades" means "rain." The name undoubtedly comes from the fact that the Mediterranean region experiences rainy seasons in May and November, just as the Hyades are setting in the early evening and early morning, respectively. In Greek mythology, the Hyades are sisters, the daughters of Aethra and Atlas and half-sisters to the Pleiades. They can be traced back to about 750 B.C., when the Greek poet Homer included the Hyades in his *Iliad* about the Trojan War.

Just how many of the Hyades sisters can you count by eye? Fifteen shine brighter than 5th magnitude, but binoculars quickly raise that number into the dozens. In fact, hundreds of stars lie inside the cluster's 5.5° span. More than 130 of them are brighter than 9th magnitude and should be visible in binoculars under reasonably dark skies.

The cluster's large apparent size poses some problems when trying to view it. It's so large that telescopes can't take it all in at once. Even some binoculars can't squeeze the cluster's full extent into their fields of view. The best view of the Hyades will be through binoculars that have fields of view between 7° and 9° in diameter. Anything less and the clustering effect will be lost; sometimes in stargazing, you can't see the forest for the trees.



TAURUS THE BULL is easy to locate with help from the bright star Aldebaran. From here, it is easy to star-hop to such dazzling star clusters as the Hyades and the Pleiades. *ASTRONOMY*: ROEN KELLY

However, one of the Hyades "sisters" is an imposter. This celestial fraud is none other than brilliant Aldebaran itself. Aldebaran does not belong to the Hyades, despite appearances. Instead, it lies in the foreground, between the cluster and us. It just happens to fall along the same line of sight. The Hyades cluster is 150 light-years from Earth, which makes it one of the closest to us, but Aldebaran is only about 65 light-years away.

The brightest true cluster star, therefore, is **Theta^2 (θ^2) Tauri** at magnitude 3.4. Theta^2 teams with 3.8-magnitude **Theta^1 (θ^1) Tauri** to form a wide naked-eye double star just southwest of brilliant Aldebaran. Can you make them both out by eye alone? Theta^2 is classified as a white giant star, which means that it is both hotter and larger than our Sun. Theta^1 is a yellow star, like the Sun. But since Theta^1 is a yellow giant, it is actually much larger than our Sun.

A careful study of the Hyades through binoculars will reveal other stellar duets and trios. Look for two fainter pairs of stars through your binoculars to the northeast and southeast of the Thetas. I also see a delta wing formed from the stars Delta, 63, 64, and 68 Tauri to the west of Aldebaran.

If you scan various deep-sky catalogs, you may find the Hyades referred to by their catalog designation, Melotte 25. This designation originated in 1915, when Philibert Jacques Melotte (1880–1961) published his *Catalogue of Star Clusters Shown on the Franklin-Adams Chart Plates*. Seven years earlier, American astronomer Lewis Boss (1846–1912) discovered the Hyades form a true open star cluster. His studies found that all of the stars are moving in the same general direction and speed within the Milky Way. Later studies also showed the Hyades share a common origin, as the stars are an average of 790 million years old. The stars in the nearby Pleiades (M45), by contrast, are only about 100 million years old.

Speaking of the Pleiades, they are also an awesome sight through just about any binoculars. Be sure to stop by and pay them a visit, as well as the Hyades, every chance you get this winter. Several other lesser-known open star clusters also lie within Taurus and are just waiting for your visit. Stop by Astronomy.com this month for some other points of call within the constellation. And that's no bull!

Next month, we'll take a camel for a ride down a celestial cascade. Until then, remember, two eyes are better than one.

ONLINE EXTRA Read about other Taurus star clusters to hunt with binoculars at www.astronomy.com/toc.

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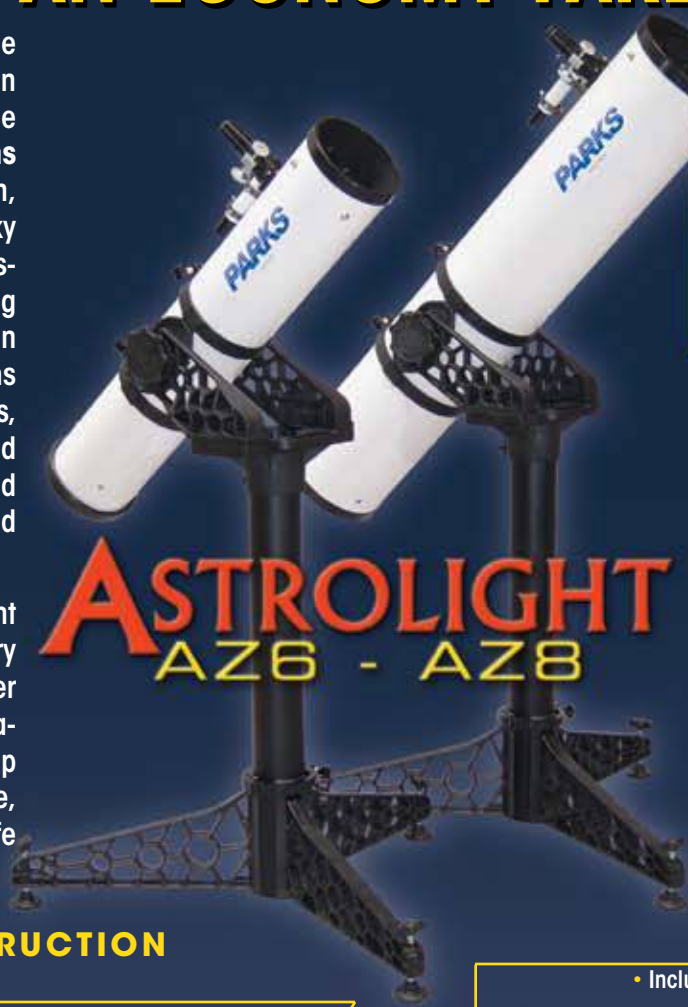

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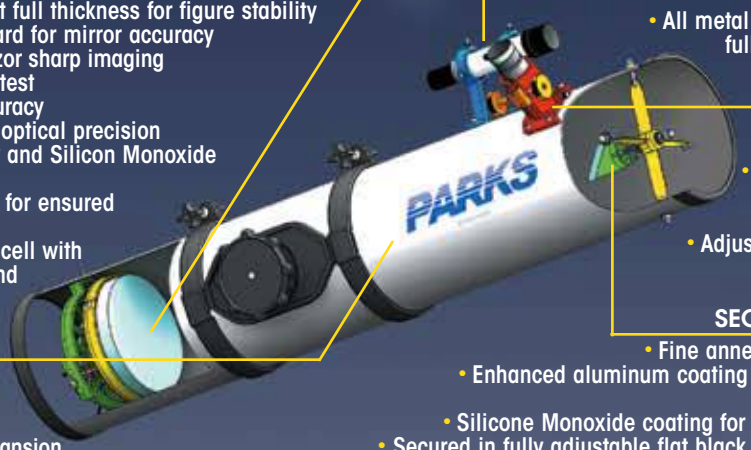

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Long haul On August 15, Voyager 1 reached 9.3 billion miles (15 billion kilometers) from the Sun. Launched in 1977, the probe is now the farthest human-made object.

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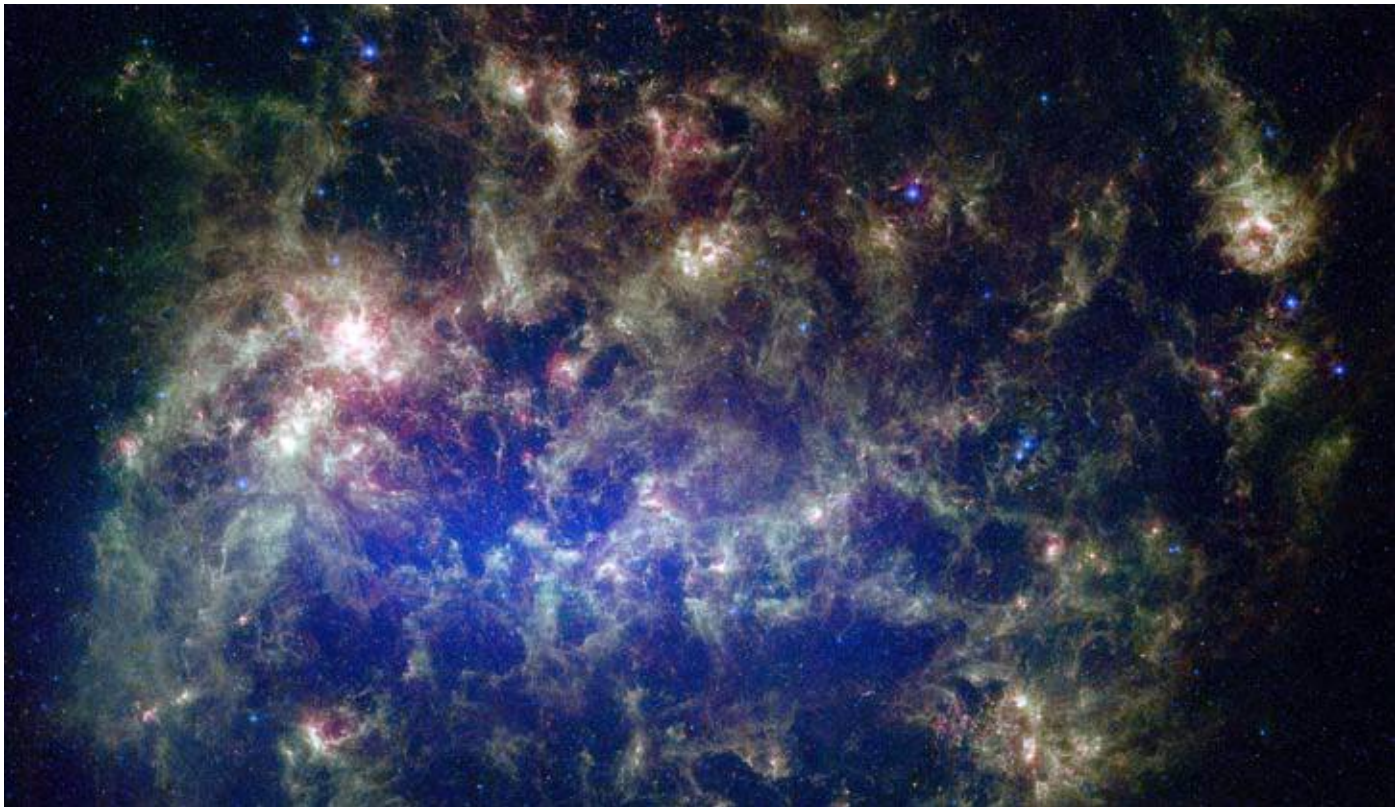


NASA/JPL-CALTECH/STScI

DUSTY DWARF. The Spitzer Space Telescope records a dusty tale in the Large Magellanic Cloud. Bright, reddish clouds show dust-rich stellar nurseries, interstellar dust appears greenish, and reddish dots show where aging stars expel dusty shells.

26 Martian springtime brings dusty jets

27 Global warming makes stronger hurricanes

28 How do you say "Fore!" in Russian?

29 Mars Express views Kasei Valles

Spitzer mosaic shows cosmic recycling

A new image from NASA's Spitzer Space Telescope helps astronomers understand how the Large Magellanic Cloud (LMC), a satellite of the Milky Way, recycles its stardust. The LMC is 160,000 light-years away.

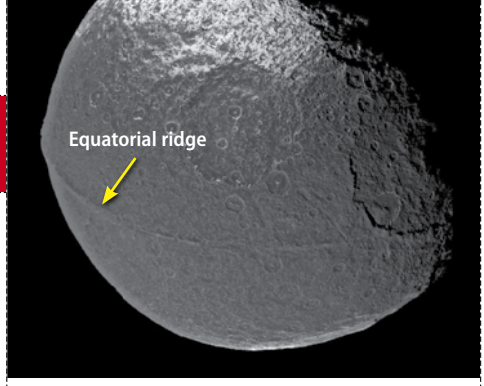
"The LMC is like an open book," says Margaret Meixner of Baltimore's Space Telescope Science Institute. "We can see the entire life cycle of matter in a galaxy in this one snapshot."

The false-color portrait is a mosaic of 300,000 separate images. The telescope's infrared sensors detect the heat of the galaxy's star-warmed dust. Developing stars and planets consume dust. Older stars create dust and return it to space. This chemically enriches future zones of star formation.

The observations provide the most detailed look yet at how this feedback process works in a whole galaxy. Says Meixner, "We can quantify how much dust is being consumed and ejected by stars."

The Spitzer mosaic also reveals nearly a million never-before-seen objects in the LMC. Most are stars, both young and old, hidden in layers of light-blocking dust; others may be distant galaxies.

"We can now see the populations of old stars and stars that are currently forming," says Karl Gordon, a team member at the University of Arizona in Tucson. The study appeared in the November *Astronomical Journal*. — **FRANCIS REDDY**



RING RIDGE. Iapetus' equatorial ridge may be the remains of its own ring. NASA/JPL/SSI

Did Iapetus once have a ring?

When the Cassini spacecraft flew past Iapetus, Saturn's third-largest satellite, in December 2004, its cameras revealed a curious ridge aligned with the moon's equator. The ridge spans 12 miles (20 kilometers) and rises 8 miles (13 km) above surrounding plains.

Most scientists think this feature formed when crustal stress built up as Saturn's gravity slowed the young moon's spin. The moon now spins once every 79 days, but it once rotated in a few hours.

But Wing-Huen Ip of Taiwan's National Central University has a different idea. He suggests young Iapetus retained a ring of debris despite Saturn's proximity. As the moon's rotation period lengthened, the ring collapsed onto it, creating the equatorial ridge. His study appears in the August 29 issue of *Geophysical Research Letters*. — **F. R.**

NASA advisers resign

NASA's Advisory Council science committee, which apprises NASA chief Michael Griffin on science-related issues, has three fewer members. Wesley T. Huntress, Jr., Charles F. Kennel, and Eugene Levy resigned August 16.

All three had criticized the space agency for limiting its science budget to 1.5-percent growth in 2007 and 1-percent annual growth through 2010. Kennel, who voluntarily resigned, wrote an article on the topic in *The Planetary Report*'s July/August issue.

Griffin asked both Huntress and Levy to resign. Levy said he was "a little unclear" whether his outspokenness on NASA's science budget triggered the action. But in an August 21 memo, Griffin left little doubt: "The scientific community … expects to have far too large a role in prescribing what work NASA should do." — **LAURA LAYTON**

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ICE JETS. **Dust-laden gas jets greet the springtime Sun on Mars' south polar cap in this illustration. The jets carve out spidery ravines, and the dust makes dark spots.**

Martian springtime brings dusty jets

Each spring, when the Sun returns to Mars' southern ice cap, carbon-dioxide-powered jets launch sprays of sand and dust skyward. Although scientists haven't seen the jets, they do see their effects: dark spots, fan-shape features, and spiders — radiating channels formed by the outflow (see "Spiders on Mars," July 2006).

Phil Christensen of Arizona State University led a team that monitored a location on Mars' southern ice cap using the THEMIS camera on NASA's Mars Odyssey spacecraft. Spots began forming when the Sun was just half a degree high. Then, over several days, they quickly became more numerous.

The spots mark vents where high-pressure CO_2 gas bursts through a 3-foot-thick (1 meter) layer of dry ice. CO_2 frost, together with surface dust and sand, migrate downward through the ice all winter long. Springtime sunlight heats the dark dust and sand, which, in turn, heats the CO_2. The ice turns to gas, and pressure builds under the icy surface until the trapped gas breaks free, taking loose dust and sand with it. The report appears in the August 17 issue of *Nature*. — **L. L.**

December 1981

25 years ago in *Astronomy*

Voyager 2's August 1981 Saturn flyby kept planetary scientists busy for decades. New images of the planet's 17 known moons showed off their surprising variety. In *Astronomy*'s December 1981 issue, Associate Editor Robert Burnham focused on the satellites in a 19-page showcase.

Since then, the number of known Saturn satellites has grown to 56. Thanks to the Cassini spacecraft and the Huygens probe it carried, we've seen a view of Titan's surface denied Voyager's cameras, which couldn't penetrate the moon's smoggy atmosphere.

December 1996

10 years ago in *Astronomy*

"Beware the Milky Way," warns Ken Croswell in *Astronomy*'s December 1996 issue. His "To kill a galaxy" looked at how the Milky Way grows by shredding and incorporating small satellite galaxies. The most dramatic evidence of this process surfaced in 1994, when a team of astronomers discovered a clump of stars moving together in Sagittarius. This stellar group is what remains of a dwarf spheroidal galaxy that is being pulled apart by the Milky Way.

Astronomers think four of the Milky Way's globular clusters — including M54 — probably originated in the dwarf. A trail of stars pulled from the disrupted galaxy arcs across the entire sky. And astronomers have identified new starry streams — the likely remains of other absorbed dwarfs. — **F. R.**

NASA/GSFC

STORM SURGE. **Hurricane Katrina bears down on the Gulf Coast August 28, 2005.**

Global warming makes stronger hurricanes

A study by James Elsner at Florida State University in Tallahassee makes the first direct link between climate change and hurricane intensity. Elsner concludes Earth's changing climate is making Atlantic hurricanes stronger, and global warming will further increase storm damage.

Elsner compared hurricane intensities over the past 50 years to two factors: average global near-surface air temperatures and Atlantic sea-surface temperatures. He found that hurricane-season air temperatures helped predict sea-surface temperatures but not vice versa. He believes the research begins "moving the debate away from trend analyses of hurricane counts and toward a physical mechanism that can account for the various observations." The study appears in the August 23 *Geophysical Research Letters*. — **F. R.**

BRIEFCASE

NASA commerce

On August 18, NASA announced plans to invest $500 million in commercial space transportation services. The agency selected Space Exploration Technologies of El Segundo, California, and Rocketplane-Kistler of Oklahoma City to develop less costly ways to reach low Earth orbit. — **F. R.**

COBE cash

The Peter Gruber Foundation's 2006 Cosmology Prize goes to the Cosmic Background Explorer (COBE) science team. COBE, launched in 1989, was NASA's first cosmology mission. Team members share $250,000 for their study of the cosmic microwave background. — **L. L.**

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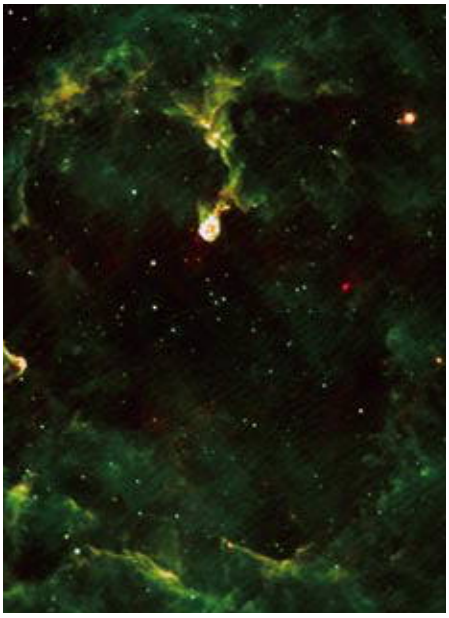
Astronomy's engine



JAXA

INFANT SUNS. Japan's Akari mapped newborn stars around the Elephant Trunk Nebula.

Akari views Cepheus star birth

Japan's Akari infrared observatory, launched February 21, is halfway through making its first far-infrared map of the sky. One target of the craft's detectors was the Elephant Trunk Nebula (IC 1396) in Cepheus. Akari imaged a 3-square-degree zone around the nebula at mid-infrared wavelengths (9 and 18 micrometers).

IC 1396 is a bright star-forming region about 3,000 light-years away. High-energy radiation from a single massive star sets most of the gas aglow. Gaseous outflows from young stars, in the image's center, have bulldozed the region's gas and dust to the nebula's edge. This is what creates the shell-like structure.

The Akari data reveal the detailed distribution of gas and dust over the entire nebula and pinpoint many previously unknown newborn stars. This will enable scientists to take a detailed census of the area's star formation. **— F. R.**

ELEMENT 21 GOLF COMPANY

ELEMENT 21 GOLF COMPANY

▲ **TEE TIME.** ISS Expedition 13 commander Pavel Vinogradov practices his golf swing.

► **SUBMERGED.** Cosmonaut Mikhail Tiourine took a golf club to underwater training August 4.

How do you say "Fore!" in Russian?

In late November, a cosmonaut will step out of the International Space Station (ISS) to swat one or two golf balls with a new club the manufacturer wants to promote. Even if the swing is shaky and the impact slight, the balls will travel millions of miles before burning up in Earth's atmosphere.

Undeniably, this will be the longest drive in golf history.

The orbital tee-off is the brainchild of several former Soviet space engineers who immigrated to Canada in the 1990s with supplies of a scandium alloy developed for space applications. It turns out the substance has beneficial properties for golf clubs. They knew little about the sport before they founded Element 21 Golf Company to manufacture the clubs.

Critics have raised the fear that free-flying golf balls might somehow loop around and hit the space station from the opposite direction. But if the cosmonaut duffer drives his shots aft, against the station's orbital motion, Newton's laws guarantee they'll never return. They will occasionally lap the station, passing a safe distance beneath it in progressively lower orbits. Air drag will accentuate their decay and increase the separation from ISS' altitude.

NASA has developed standards for throwing things off the station. In mid-2007, astronauts will dispose of a half-ton fluid tank set that will no longer be needed when the space shuttle arrives with new hardware. Once an astronaut gives this piano-size hunk of space junk a push, it will be clearly visible to skywatchers for a year or more. And, like the golf balls it follows, the tank is going on a one-way trip.

The golf-ball stunt won't be the first time Russian cosmonauts have performed commercials in orbit. One memorable episode involved a human-size inflatable soft-drink can cast off from the Mir space station. And, thanks to free publicity over the golf-ball stunt, the club manufacturers won't be the last space-minded businessmen to rent a cosmonaut. **— JAMES OBERG**

ESA/DLR/FU BERLIN (G. NEUKUM)

MARS SCAR. **Ancient floods carved Kasei Valles, one of the Red Planet's largest outflow channels.**

Mars Express views Kasei Valles

On August 30, the European Space Agency released perspective views of Kasei Valles. Gigantic floods early in Mars' history probably formed the 310-mile-wide (500 kilometers) valley. Glacial activity subsequently modified the terrain.

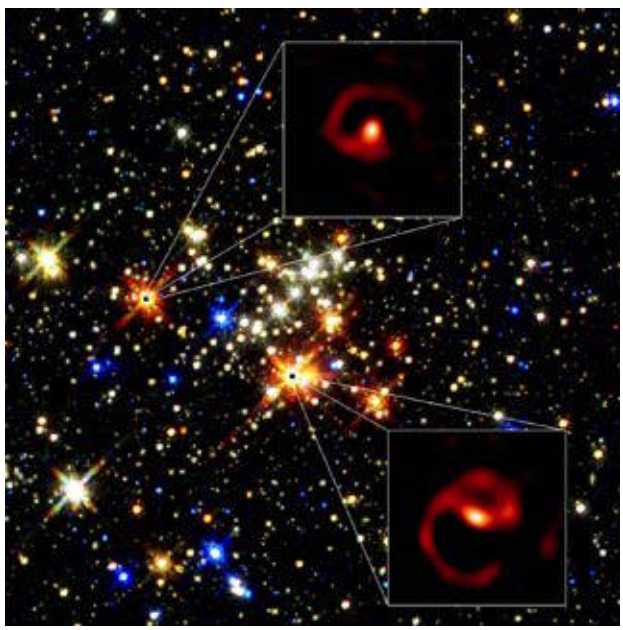
Kasei Valles, one of Mars' largest outflow channel systems, connects the southern Echus Chasma to the plains of Chryse Planitia, where NASA's Viking 1 landed in 1976. Including Echus Chasma, the valley spans 1,500 miles (2,500 km). "Kasei" is the Japanese word for Mars.

The Mars Express High Resolution Stereo Camera returned the image in February 2005. Scientists used height data to create the view. — **F. R.**

Quintuplet stars sport "pinwheels"

The discovery of dusty pinwheels around two stars in the Milky Way's Quintuplet cluster reveals each contains at least two stars.

A team led by Peter Tuthill, an astrophysicist at Australia's University of Sydney, investigated the cluster's brightest stars using the giant telescope at Keck Observatory in Hawaii. "Only a few pinwheels are known in the galaxy," says team member Don Figer, an astronomer at the Rochester Institute of Technology in New York. "We've found five all next to each other in the same cluster."



KECK OBSERVATORY/PETER TUTHILL AND DON FIGER

WINDBLOWN. **Dusty corkscrews whirl from the Quintuplet cluster's bright binary stars.**

Quintuplet is named for its five prominent Wolf-Rayet stars, but a light-reddening dust shroud surrounds each one. The new images allowed the team to see that the dust forms spirals — the signature of a binary companion. The dust forms when a star's violent outflow collides with a similar outflow from its orbiting companion. The findings appeared in the August 18 issue of *Science*. — **F. R.**

QUICK TAKES

SPACE-TOURISM FIRST

The **first female space tourist**, Iranian-born Anousheh Ansari, a Dallas businesswoman, reached the International Space Station (ISS) September 20. The 10-day trip cost her $20 million.

BREATHE EASY

On September 18, ISS shut down the Russian-built Elektron **oxygen generator** when smoke began issuing from a rubber gasket. A small amount of potassium hydroxide, a toxic liquid, may have leaked from the device's oxygen vent.

BUBBLE UP

South Africa's **Sumbandilasat** imaging satellite is scheduled for launch this month. It will take to space aboard a converted missile fired from a Russian submarine in the Barents Sea.

FAST MARKS A DECADE

On August 21, NASA's **Fast Auroral Snapshot** (FAST) satellite completed its 40,000th orbit. FAST has spent a decade studying Earth's aurora borealis and australis, also called the northern and southern lights.

LIFE CHANGES

Planet-hunters think understanding how life changed Earth's atmosphere will help **predict life's presence** on alien worlds. Lisa Kaltenegger (Harvard-Smithsonian Center for Astrophysics) and Wesley Traub (NASA's Jet Propulsion Laboratory) say the state of Earth's atmosphere at various points in the past will enable scientists to determine the presence of any life on an extrasolar planet. The technique may also reveal the alien life's evolutionary stage.

SEEING STARS

NASA's **Pluto-bound New Horizons** captured its first image — a snapshot of open cluster M7 — August 29. The craft's Long Range Reconnaissance Imager (LORRI) was the last of the probe's five science instruments tested. — **F. R.**

Does anti

Matter edged out antimatter to make possible the universe we know. But no one yet knows how.

/// BY RAY JAYAWARDHANA

Astronomers often muse about the vast emptiness of the cosmos. Of course, the universe contains lots of matter — galaxies, stars, planets, and people. But this rather obvious statement belies one of the deepest cosmic mysteries: Why does matter exist at all? Why isn't the universe just a sea of radiation?

Scientists think the universe just after the Big Bang was so full of energy that subatomic particles — and their antimatter equivalents — briefly popped into existence. When a particle of matter, like an electron, runs into its antiparticle (a positron), they annihilate each other in a burst of radiation. But the early cosmos was so dense — and the matter-antimatter particle pairs packed so tightly — that the particles should have quickly annihilated one another, leaving only radiation.

Because that's not the case, scientists think there must have been a slight preponderance of matter over antimatter. Physicists have worked out the magnitude of this asymmetry: For every billion antiparticles, there must have been a billion-plus-one particles of matter. All things in the universe today — including us — owe their existence to this seemingly insignificant matter excess.

How that excess came about is among the most fundamental yet elusive questions in particle physics. The standard model of particle physics is remarkably successful at explaining

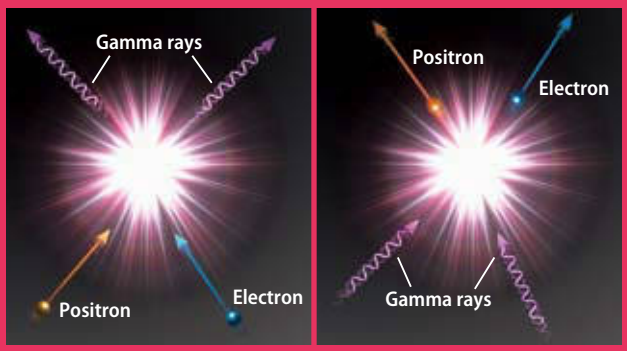
Contributing Editor **Ray Jayawardhana** *teaches astronomy and astrophysics at the University of Toronto.*

matter matter?

WHEN MATTER and antimatter particles collide, they annihilate one another in a gamma-ray flash. NASA's Compton Gamma-Ray Observatory found a vast region near the center of our galaxy emitting this process' characteristic radiation. Part of the structure is a jet that blasts hot gas and antimatter out of the galaxy's plane.

ADOLF SCHALLER FOR *ASTRONOMY*

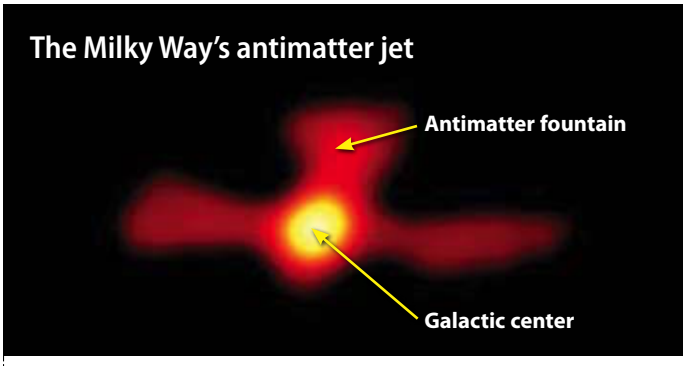
Producing and annihilating pairs



ASTRONOMY: ROEN KELLY

THE EQUIVALENCE of matter and energy means that each can take on the identity of the other. The collision of electrons and positrons produces a pair of gamma rays. Likewise, colliding gamma-ray photons can make electrons and positrons.

The Milky Way's antimatter jet



NASA'S Compton Gamma-Ray Observatory revealed gamma rays produced by electron-positron annihilation in the Milky Way's heart. The galactic center, thought to contain a supermassive black hole, is the bright central region. It lies within a 4,000-light-year-wide cloud of emission in the galaxy's plane. What astonished researchers was a faint lobe of emission rising out of the plane — a jet of hot gas and antimatter 3,500 light-years long. NASA/W. PURCELL ET AL.

the world around us in terms of a mere dozen fundamental particles — plus their antimatter doppelgangers. The model explains their various interactions through the exchange of "force carrying" particles like photons. Countless experiments have verified the model's predictions to amazing precision. Yet, the standard model's inability to explain why the universe so clearly favors matter over antimatter has remained a stubborn thorn in its side.

"It could be that this asymmetry really points to something beyond the standard model," says Edward "Rocky" Kolb of Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois. "That's why particle physicists are so interested in this problem."

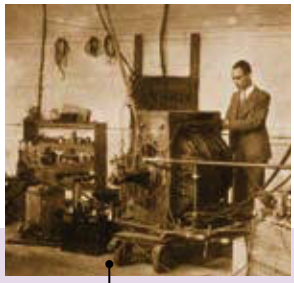
Antimatter's story

In 1928, a young British physicist named Paul Dirac combined special relativity and the newly developed theory of quantum mechanics into a mathematical equation describing an electron's behavior. His equation implied that for every particle, there's a corresponding antiparticle — a sort of mirror image having the same mass but opposite in all other respects, such as spin or electric charge.

Just 4 years later, Carl Anderson of the California Institute of Technology noticed a track left by "something positively charged, and with the same mass as an electron" while studying cosmic rays. After about a year of investigations, he decided these new particles were antielectrons, which he called positrons. Dirac was awarded a Nobel Prize in 1933 for his theoretical prediction, and Anderson received one 3 years later for his experimental discovery.

The antiproton and antineutron were identified in the 1950s in a particle accelerator named the Bevatron in Berkeley, California. Two independent groups observed the first antinucleus, made of an antiproton and antineutron, in 1965.

But it wasn't until 30 years later that scientists produced the first antiatoms, with a positron orbiting an antinucleus. In 1995, a team of physicists built up nine "antihydrogen" atoms at the European Organization for Nuclear Research, better known as CERN, near Geneva. Today, efforts continue at CERN to make large quantities of antihydrogen. The trick is storing the antiatoms long enough that scientists can study their behavior.

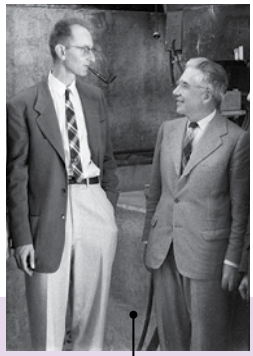


Breaking the rules

Since the 1960s, scientists have puzzled over the prevalence of matter in the universe because it suggests the breaking of symmetry at a fundamental level. The idea of symmetry is central to physics. In 1915, German mathematician Emmy Noether proved that symmetry implies a conservation law and vice versa.

For example, if a decaying muon emits an electron to the right, then an anti-muon should emit the electron to the left. This property is known as parity (or handedness). It should be conserved in particle interactions, along with other quantities such as charge.

However, the standard model allows these symmetries to break down occasionally, in a phenomenon called the charge-parity, or CP, violation. So, once in a



Discovering antimatter

AIP EMILIO SEGRÈ VISUAL ARCHIVES

1928
Paul Dirac combines quantum theory and special relativity into an equation for electrons that implies antiparticles exist.

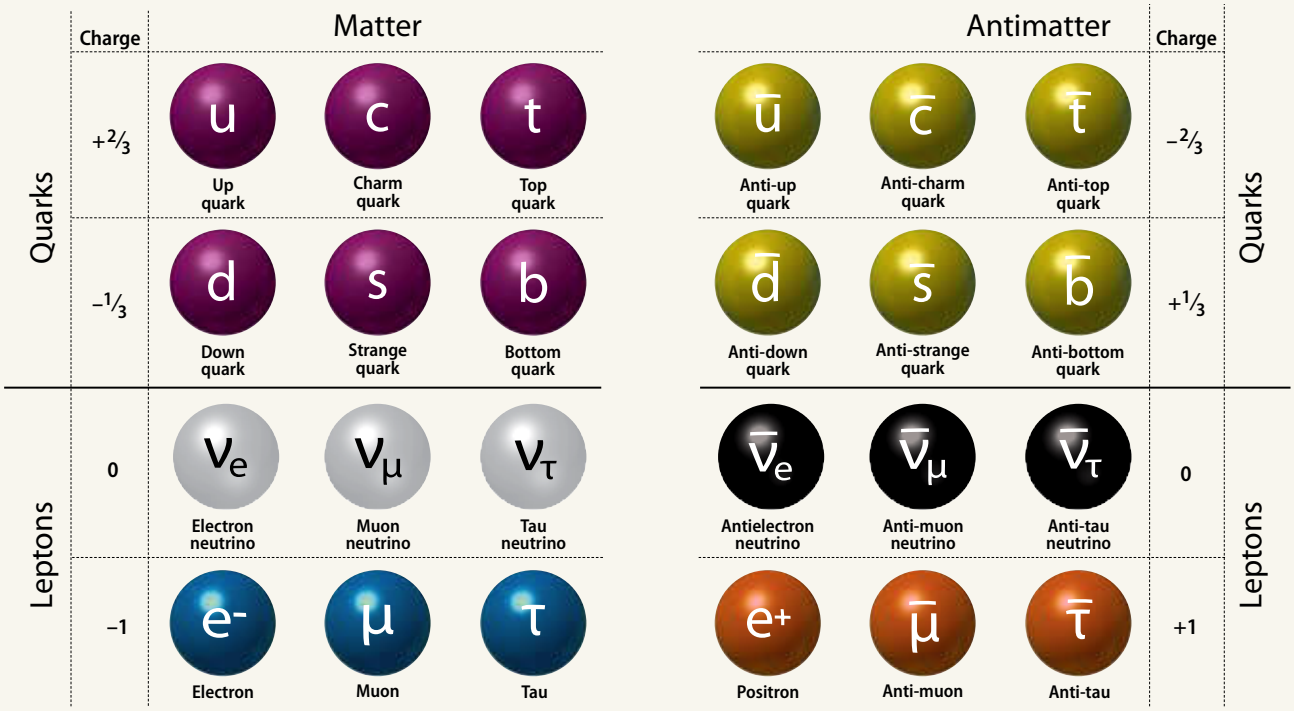
1932
Carl Anderson detects positrons from cosmic-ray showers in cloud chamber experiments.
AIP EMILIO SEGRÈ VISUAL ARCHIVES

1933
Dirac wins Nobel Prize in physics.

1936
Anderson wins Nobel Prize in physics. Both he and Dirac won the prize at the age of 31. They tie as the second youngest Nobel laureates.

1955
Emilio Segrè (right) and Owen Chamberlain discover antiprotons using the Bevatron at the University of California, Berkeley. AIP EMILIO SEGRÈ VISUAL ARCHIVES

A visit to the particle zoo



ALL MATTER is made up of atoms, which, in turn, contain baryons and leptons. Baryons, such as protons and neutrons, are made up of even smaller particles called quarks. Quarks come in six flavors and stick together by the strong nuclear force. Leptons, such as electrons and neutrinos, are fundamental particles. Each quark and lepton has an antimatter twin, with the same mass but opposite charge and magnetic spin. For example, an electron and a positron have the same mass, but one has a charge of –1 while the other has a +1 charge. Just as quarks combine to make baryons, antiquarks form antibaryons. *ASTRONOMY:* ROEN KELLY

while, an anti-muon decays by launching an electron to the right.

In 1964, a team of physicists working at the Brookhaven National Laboratory on Long Island, New York, first observed CP violation during the decay of electrically neutral particles called kaons. But, the effect was tiny — nowhere near enough to account for matter's dominance over antimatter. Since then, physicists have been searching for other instances of CP violation that might boost the numbers.

Two of the most sensitive experiments — one named BaBar at the Stanford Linear Accelerator in California and another called Belle at the High Energy Physics Laboratory in Japan — started operations in 1999. These "B factories" smash together electrons and positrons at nearly light-speed to create a shower of neutral particles known as B mesons, which disintegrate in a trillionth of a second into a variety of other exotic species. By recording hundreds of millions of such decays, physicists measured a 13-percent asymmetry in the decay rates of B mesons compared to those of anti-B mesons. This B/anti-B asymmetry is the most severe case of CP violation yet seen.

Unfortunately, that's still far from sufficient to account for the universe's matter-antimatter

1956

Bruce Cork (standing, center) at California's Lawrence Berkeley National Laboratory leads a team using the Bevatron that discovers antineutrons. All three constituents of the atom have an antiparticle. AIP EMILIO SEGRÈ VISUAL ARCHIVES

Tsung Dao Lee (Institute for Advanced Study, Princeton) and Chen Ning Yang (Columbia University) conclude that weak interactions, like radioactive beta decay, break parity symmetry.

1957

Chien-Shiung Wu (Columbia University) shows that decaying cobalt-60 nuclei emit more electrons in one direction than another, violating parity symmetry.

Lee and Yang share the Nobel Prize in physics.

1959

Segrè and Chamberlain share the Nobel Prize in physics.

Excited faculty shared the news with students through the chalkboard message above. BERKELEY LAB LIBRARY

1964

James Cronin (University of Chicago) and Val Fitch (Princeton) show decaying K-mesons violate CP (charge-parity) symmetry.

ANTI-SPEAK

BELLE
An experiment at Japan's High Energy Physics Laboratory in Tsukuba. It's looking for symmetry violations in B mesons and their antiparticles.

COSMIC RAYS
High-energy particles, either atomic nuclei or electrons, that originate from the Sun and from sources beyond the solar system, such as supernova remnants.

CP SYMMETRY
Charge-parity symmetry. Most elementary-particle interactions occur in the same way when the particles' electric charge or spatial coordinates are swapped.

NOvA
NOvA stands for NuMI Off-axis ν_e (electron neutrino) Appearance experiment. Located in Minnesota, the experiment will look for neutrinos beamed to it from Fermilab in Illinois.

PAIR PRODUCTION
The process by which an electron and a positron result from the collision of two gamma-ray photons or, more commonly in the laboratory, a single interaction with an atomic nucleus.

POSITRON
A positively charged particle with the same mass as the negatively charged electron; the antielectron, discovered in 1932.

AIP EMILIO SEGRÈ VISUAL ARCHIVES

WHERE IS ANTIMATTER?

Among energetic particles called cosmic rays, which originate from the far reaches of the Milky Way and bombard Earth every day, protons outnumber anti-protons 10,000 to 1. This suggests there isn't much antimatter in our vicinity of the galaxy.

One exception is the galactic center, where for decades astronomers have recorded gamma-ray emission caused by matter-antimatter annihilation. But astronomers don't see vast regions like this in the far universe, so it seems unlikely antimatter galaxies — or even large clouds of antihydrogen — exist.

Just how rare is this stuff? In 1998, a 4-ton instrument called the Alpha Magnetic Spectrometer flew aboard space shuttle Discovery to look for antihelium nuclei among cosmic rays. The device's huge superconducting magnet and six sensitive detectors captured millions of helium nuclei, but none of their antimatter twins.

AMS COLLABORATION

AMS-02 will look for antimatter from the International Space Station.

A more advanced version of this instrument is slated for a 2008 launch to the International Space Station, where it will look for antimatter for 3 years. — *R. J.*

asymmetry. So, the search continues. One of the five major experiments to be carried out with the Large Hadron Collider (LHC), now under construction at CERN, is expected to look for additional sources of CP violation. When completed in 2007, LHC will become the world's most powerful particle accelerator. It occupies a circular tunnel some 16.8 miles long (27 kilometers) near the Swiss-French border.

Meanwhile, theorists have dreamt up several other ways to generate a stronger asymmetry. Some of these are rather complicated, if not downright contrived. Fermilab's Kolb describes the more outlandish suggestions as "constructing a grand edifice to explain this single number."

One idea is that the evaporation of primordial black holes, formed in the infant universe, did not conserve symmetry.

Another explanation that looks more promising — thus, a current favorite — is that the asymmetry originates in the class of particles known as leptons, which includes the electron and the ghost-like neutrino.

Enter the neutrino

Wolfgang Pauli, a giant in the development of quantum mechanics, first invoked neutrinos in 1930 as a "desperate remedy" to account for missing energy in a nuclear disintegration process known as beta decay. In beta decay, a neutron breaks into a proton and an electron — plus something else that flees the scene and carries some energy with it.

Pauli proposed the neutrino to explain the missing energy. These uncharged particles rarely interact with matter, making it rather difficult to pinpoint their characteristics. Tens of trillions of neutrinos, most of them produced in nuclear reactions in the Sun's core, pass through our bodies every second without leaving a trace.

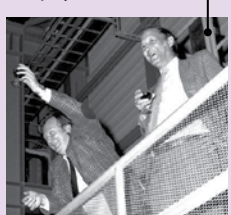
In fact, neutrinos were not detected experimentally until 1956, a quarter of a century after Pauli's prediction. Physicists once considered neutrinos to be massless,

1965
Two teams of physicists, one led by Antonino Zichichi (CERN) and the other by Leon Lederman (above) of Brookhaven National Laboratory in New York, simultaneously make an antideuteron (an antiproton bound to an antineutron).

1980
Cronin and Fitch win the Nobel Prize in physics.

1980s
CERN's Simon van der Meer invents a method to control antiproton beams. Using the resulting proton/antiproton collider at CERN (shown above), Carlo Rubbia discovers the W and Z bosons, carriers of the weak force. CERN

1984
Rubbia (left) and van der Meer share the Nobel Prize in physics. CERN



1995
At CERN, the PS210 experiment led by Walter Oelert and Mario Macri produces nine hot antihydrogen atoms.

Hydrogen versus antihydrogen

ASTRONOMY: ROEN KELLY

TAKE TWO up quarks and a down quark, which together form a proton, then add an orbiting electron, and you have a hydrogen atom. To make antihydrogen, scientists combine two anti-up quarks, an anti-down quark, and an orbiting positron.

but now scientists agree neutrinos have some, albeit small, mass. Data collected at vast underground detectors — at SuperKamiokande in Japan and Sudbury Neutrino Observatory in Canada — have shown that neutrinos, which come in three "flavors," can change from one type to another. Such oscillations can happen only if neutrinos have mass, although their exact mass hasn't been measured yet.

Some physicists think the early universe was filled with super-heavy counterparts to the lightweight neutrinos observed today. When these super-heavy neutrinos decayed, they may have had a slightly higher probability of making matter rather than antimatter. Unfortunately, no accelerator has sufficient energy to create these hefty particles, so scientists have to infer whether this could have been the case by carefully observing the properties of the super-heavy neutrinos' lighter cousins.

In the late 1930s, a reclusive Italian physicist named Ettore Majorana suggested all neutrinos could have a strange property. While most elementary particles have a corresponding antimatter particle, usually with opposite charge and spin, neutrinos could be their own antiparticles. If he is right, two neutrons can undergo beta decay together so that the antineutrino emitted by one is immediately absorbed by the other. The net result is two neutrons disintegrating simultaneously without releasing any antineutrinos. Physicists call this hypothetical process "neutrino-less double beta decay." Of course, it would be rare, but observing it could be the key to unlocking the mystery of the matter-antimatter asymmetry.

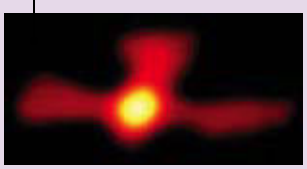
If Majorana turns out to be right and neutrinos and antineutrinos are equivalent, super-heavy neutrinos in the newborn universe could have violated CP symmetry enough to tip the balance in favor of matter. A number of sophisticated particle physics experiments are already underway — in France, Italy, Switzerland, and elsewhere — to search for neutrino-less double beta decay. No definitive signal has turned up yet.

Physicists plan several more sensitive experiments. One of them, called NOvA, will consist of a giant tank filled with 24,000 tons of scintillator oil in northern Minnesota. The oil will detect neutrinos beamed through Earth from Fermilab some 500 miles (800 km) away. Once NOvA is completed in the next decade, scientists hope that it, and experiments like it, will be able to see a possible asymmetry in the way the three types of lightweight neutrinos morph into one another.

Physicists want to get to the heart of why the early universe so favored matter. To do so, they're building complex experiments that collect and study antimatter or peer into rare rule-breaking interactions. Sooner or later, these experiments will help scientists unravel one of the cosmos' most fundamental mysteries — why matter exists at all.

ONLINE EXTRA Can antimatter be used for space travel? Visit www.astronomy.com/toc.

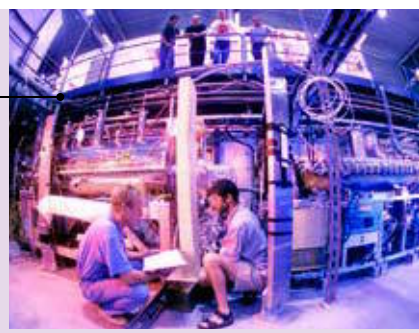
1997
Astronomers discover the Milky Way's "antimatter fountain."



1999
CERN activates its Antiproton Decelerator (AD), a first step in slowing and cooling antihydrogen so it can be studied. CERN

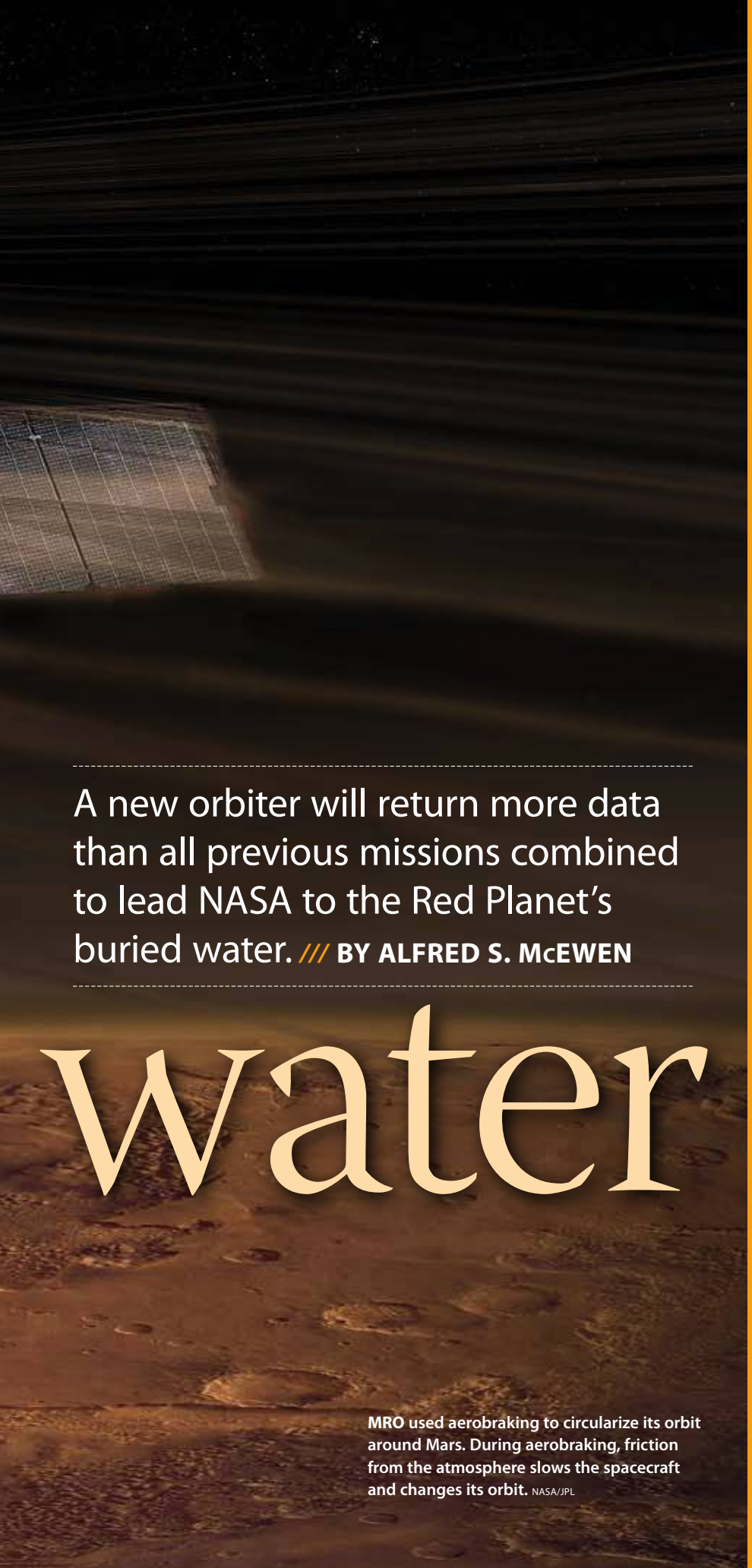
2002
The ATHENA experiment at CERN produces 50,000 cold antihydrogen atoms.

2003
ATHENA's antihydrogen production passes the 2-million-atom mark. CERN



Mars Reconnaissance Orbiter

Zeroing in on martian



A new orbiter will return more data than all previous missions combined to lead NASA to the Red Planet's buried water. /// **BY ALFRED S. McEWEN**

water

MRO used aerobraking to circularize its orbit around Mars. During aerobraking, friction from the atmosphere slows the spacecraft and changes its orbit. NASA/JPL

When the Mars Reconnaissance Orbiter (MRO) went into orbit around Mars March 10, it brought a whole new approach to exploration of the planet. The NASA vehicle, launched August 12, 2005, carries six instruments designed to advance the search for life on Mars dramatically.

The instruments are the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM); the Context Camera (CTX); the High Resolution Imaging Science Experiment (HiRISE); the Mars Climate Sounder (MCS); the Mars Color Imager (MARCI); and the Shallow Subsurface Radar (SHARAD). The instruments observe Mars in near-ultraviolet, visible, infrared, and radio wavelengths.

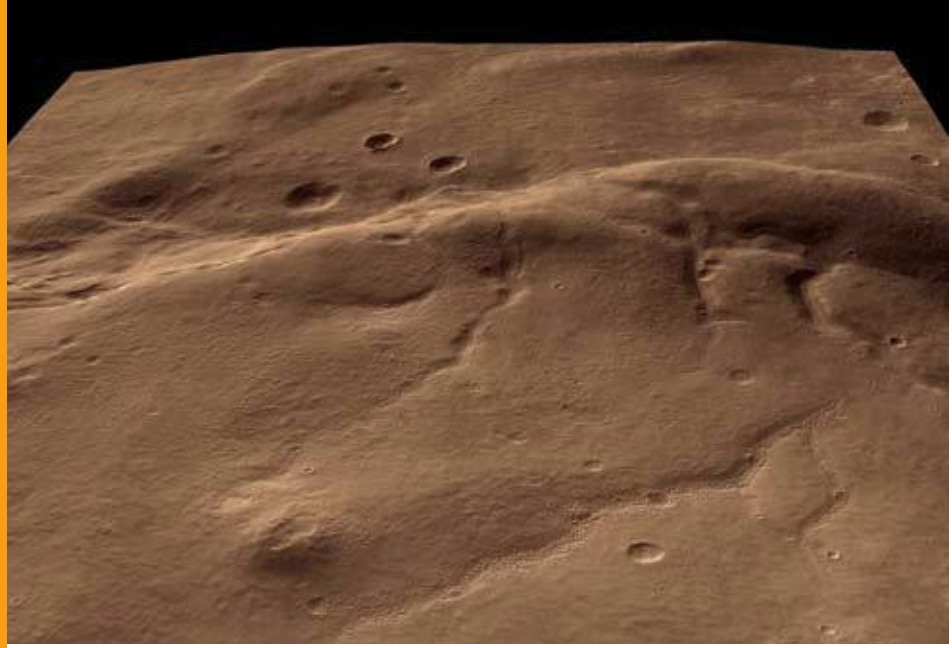
MARCI will acquire daily global color (near-ultraviolet to visible) Mars images to monitor dust and condensate hazes, clouds in the atmosphere, and frost and dust on the surface. This monitoring will help us understand how the planet's surface affects its atmosphere and determine the best times and seasons for aerial photography.

MCS will almost continuously scan Mars' surface and the edge of its atmosphere. The data collected will enable Mars climatologists to follow water, carbon dioxide, and dust from surface sources to different atmospheric levels and back to the surface. Knowing the current atmospheric system is the first step toward understanding Mars' past climates.

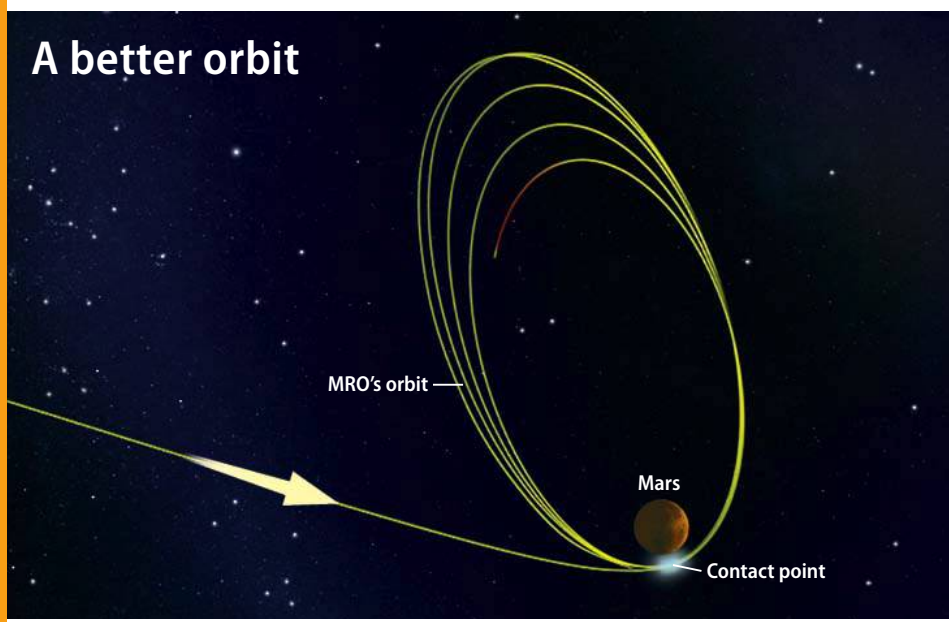
The Italian Space Agency provided MRO's SHARAD instrument, as well as the MARSIS radar-sounding experiment on Mars Express, orbiting Mars since 2003. MARSIS detected large-scale subsurface structures, such as the base of the polar cap and large buried craters. SHARAD probes at a higher frequency than MARSIS and has greater resolution. SHARAD should be able to map the distribution of loose materials, rock, ice, and water to depths as great as a half mile (1 km), with about 30 to 65 feet (10 to 20 meters) vertical resolution. Detection of water within about a mile of the surface could lead to a mission to drill down to the water and search for life.

CRISM will map Mars' mineralogy at high spatial resolution. The CRISM team is

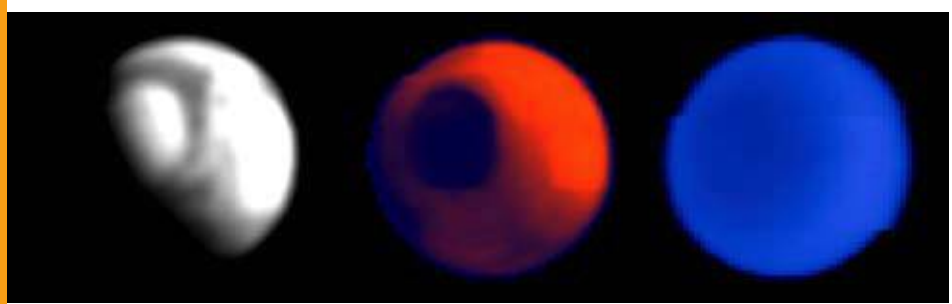
Alfred S. McEwen *is principal investigator for the Mars Reconnaissance Orbiter's High Resolution Imaging Science Experiment (HiRISE).*



THIS PERSPECTIVE generated from digital topography has a field of view 55° wide with no vertical exaggeration. Taken during autumn in Mars' southern hemisphere, the image shows how a ridge has deformed several valleys and impact craters. NASA/JPL/UNIVERSITY OF ARIZONA/USGS



AEROBRAKING is a process using Mars' atmosphere to place MRO in a circular orbit. The spacecraft initially entered a 35-hour orbit. After 6 months, when MRO completed aerobraking maneuvers, each orbit now lasts approximately 2 hours. NASA/JPL-CALTECH



THE MARS CLIMATE SOUNDER monitors daily changes in Mars' atmosphere. Its first images, taken March 24, show three different wavelength bands. The view on the left shows reflected sunlight. The center view shows infrared surface radiation where the atmosphere is clear (red) and dust cloud radiation where it's not (blue). The view on the right shows only infrared radiation from the atmosphere. NASA/JPL-CALTECH

particularly interested in minerals that form only in the presence of water, such as the clays discovered by the imaging spectrometer on Mars Express. When water evaporates, it leaves behind traces of iron, oxides, clays, salts, or carbonates. Finding places rich in such deposits will make good targets for future landers and rovers.

The HiRISE camera will image Mars at scales ranging from 1" to 1¼" (25 to 32 centimeters) per pixel, including stereo imaging for topography. HiRISE images are crucial to choosing safe landing sites for future landers and rovers. Astronomers also want to see the rocks and structures a few feet long to understand the geologic history of Mars better. Scientists expect HiRISE to acquire about 10,000 images covering about 1 percent of the surface per martian year (almost 2 Earth years).

CTX will acquire images (including stereo pairs) at a resolution of about 20 feet (6m) per pixel over swaths about 18.6 miles (30 km) wide. CTX will acquire global coverage if the mission maps for 4 to 6 years.

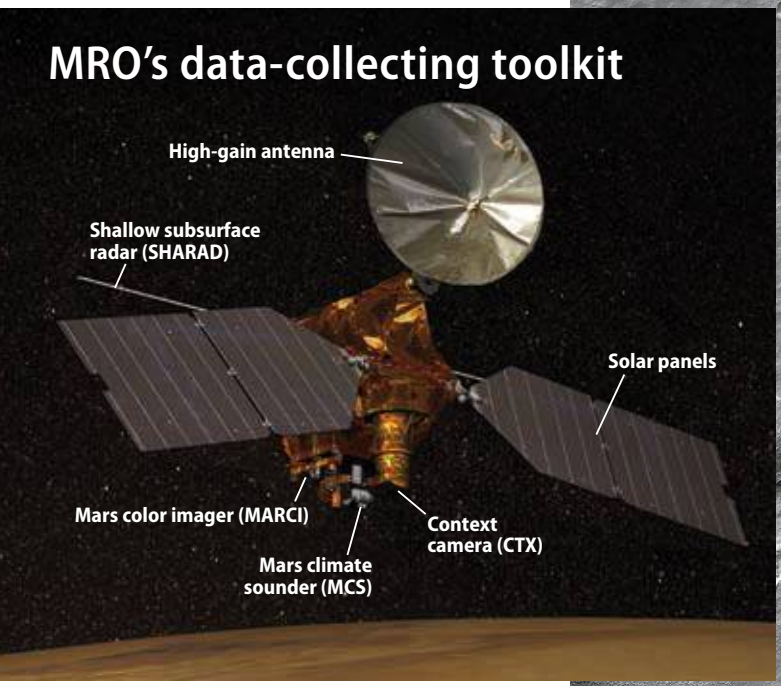
MRO, therefore, will deliver the following: a global "base map" with high resolution and fairly uniform illumination; global CRISM multispectral data; SHARAD mapping of subsurface interfaces over much of Mars' upper kilometer; and high-resolution CRISM and HiRISE coverage of the best locations. This will be a dataset that will rival that available for Earth.

MRO's role

MRO likely won't discover life on Mars, but the orbiter will advance Mars exploration in myriad ways, including future surface exploration. It will provide the reconnaissance needed to select the best future landing sites and act as a relay satellite so future landers and rovers can return more data than past surface experiments.

Three other orbiters and two rovers actively collect martian data now. The phenomenally successful Spirit and Opportunity rovers have continued operations 10 times longer than their 90-day nominal missions. The orbiters include Mars Global Surveyor (MGS), which arrived at Mars in 1997; Mars Odyssey, which entered orbit in 2001; Mars Express, which arrived near the end of 2003; and MRO, which reached the Red Planet March 10 of this year.

MRO first settled into a highly elliptical 35-hour orbit. Aerobraking, via dips into the atmosphere, in April through August



MRO carries instruments designed to "Follow the water" while the spacecraft orbits Mars. *ASTRONOMY:* ROEN KELLY, AFTER NASA

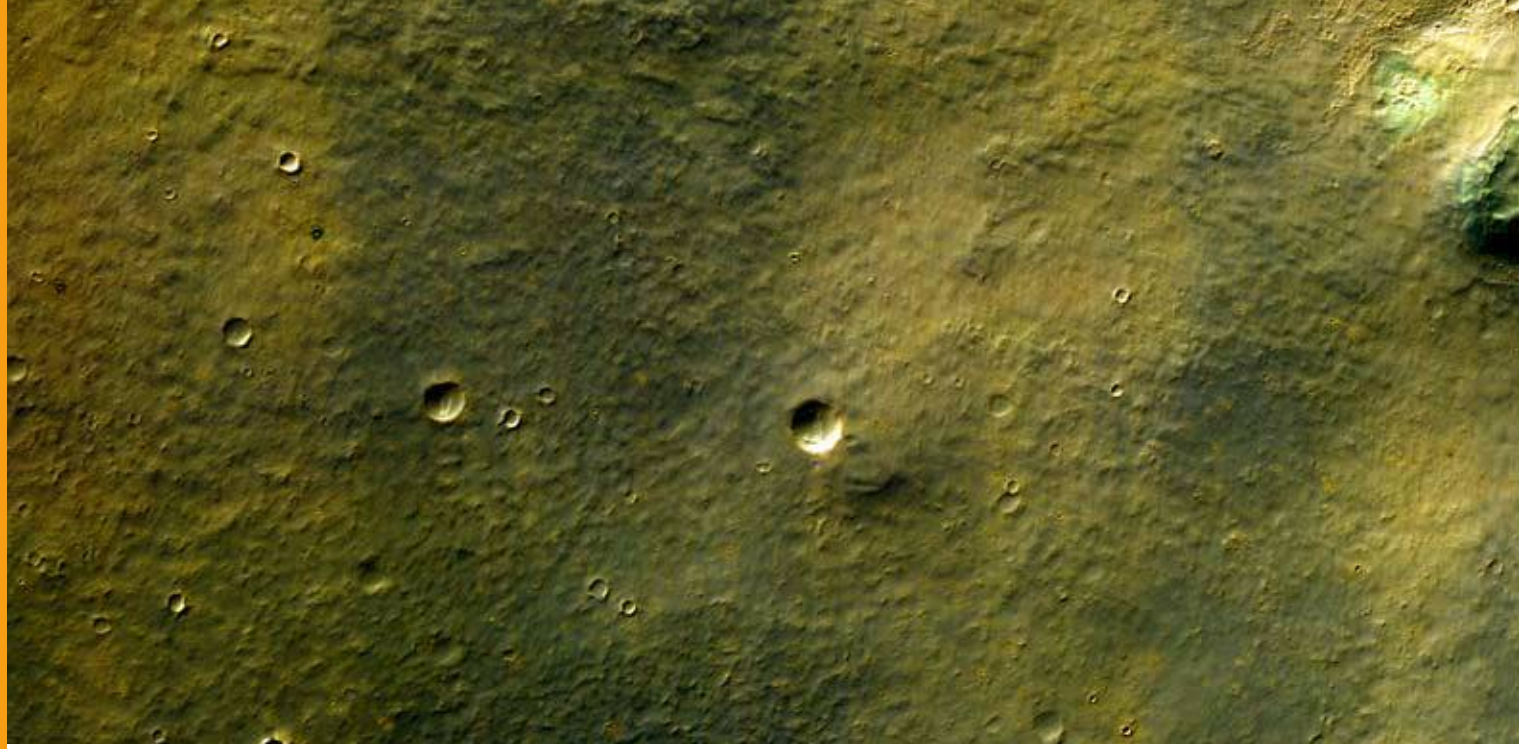
2006, circularized MRO's orbit and reduced its period to 2 hours. Its final orbit varies in altitude from 160 miles (255 km) over Mars' south pole to 200 miles (320 km) over the north pole. MGS and Odyssey orbit roughly 250 miles (400 km) up.

Water: the big question

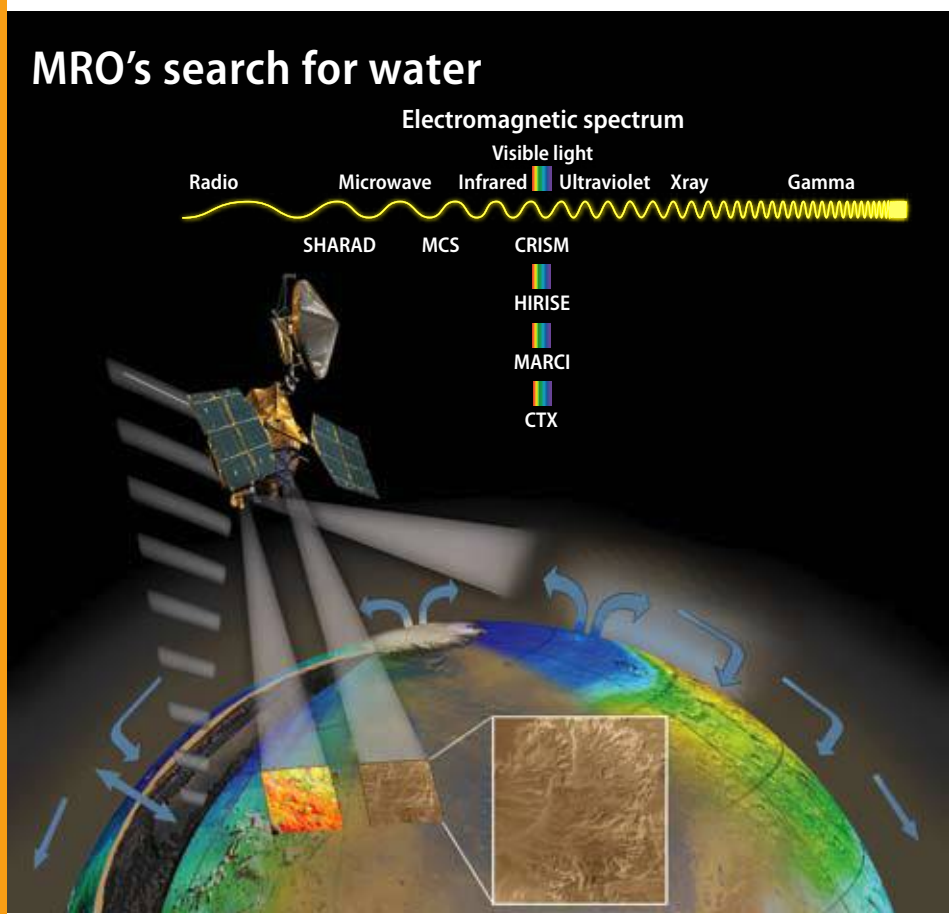
In the 18th and 19th centuries, debates raged about Earth, such as whether basalt was volcanic or a chemical precipitate. Scientists also argued about Earth's age, and about the reality of mass extinctions, ice ages, and continental drift. Information from new technologies eventually resolved these debates. Current debates about Mars are equally wide-ranging.

The major science question driving Mars exploration is whether there is or was life on that world. Scientists can devise tests for life, but they need to know where to collect samples. Clearly, life isn't abundant on the surface, and fossils would be preserved only under special conditions.

THE FIRST IMAGE from the High Resolution Imaging Science Experiment (HiRISE) on NASA's Mars Reconnaissance Orbiter shows Mars' Bosporos Planum region, centered at 33.65° south latitude and 305.07° east longitude. The area shown measures 31 miles (49.9 km) long by 14.7 miles (23.7 km) wide. HiRISE took this image March 24, 2006. NASA/JPL/UNIVERSITY OF ARIZONA



HiRISE took its first color picture March 24, 2006, combining images from detectors sensitive to red, green, and near-infrared light. The right of the image appears brighter and bluer than the left, possibly because of early morning atmospheric fog. NASA/JPL/UNIVERSITY OF ARIZONA



"FOLLOW THE WATER" is NASA's science theme. MRO's science instruments monitor Mars' present atmospheric water cycle and the associated deposition and sublimation of water ice on the surface. MRO also probes the subsurface to see how deep the water-ice reservoir extends. At the same time, it searches for surface features and minerals that record the extended presence of liquid water on Mars' surface. NASA/JPL

Researchers, therefore, need to understand the environments and processes on Mars, especially the history of water.

What were Mars' ancient climates? Evidence for dramatic change comes from the fact that only ancient terrains covered by large-impact structures have been deeply eroded. But no consensus exists about how much water was at the surface, how long it lasted, and whether life could have existed on or near Mars' surface.

Evidence for milder conditions came from OMEGA, the imaging spectrometer on Mars Express. OMEGA mapped concentrations of clay minerals, which form as water weathers volcanic rocks.

Many small clay exposures may exist that CRISM can map. HiRISE and CTX can place these deposits in detailed stratigraphic sequence. Perhaps clays formed at many places and times, and MRO will reveal a history of climate change.

What can we learn about more recent climate change, the type that will occur again in the future? Mars' rotational axis tilts 25° from the plane of its orbit, so Mars experiences seasons like Earth. But Mars' tilt is now similar to Earth's only by coincidence, because its tilt periodically changes from near 0° to as high as 60° or more.

Images from the Mars Orbital Camera (MOC) on the Mars Global Surveyor (MGS) show a mid-latitude (between 30° and 60° north and south) debris mantle that was partially removed in places over north or south-facing slopes. This debris could be dusty snow deposits that formed

when Mars had a different climate. The mantle is geologically young because it covers all of the large — greater than a half mile (1 km) in diameter — craters, but scientists can't determine yet if that means younger than 10 million or 10,000 years.

Mission scientists know the gullies discovered by MGS/MOC are younger than the mid-latitude debris mantle because the gullies lie atop it. The gullies probably required water to form because they mostly occur on slopes too shallow for avalanches. High-resolution topographic data from MRO will enable scientists to construct detailed models of gully formation. Perhaps SHARAD will detect shallow subsurface water near some of the gullies.

Relating surface features to climate-change models would advance scientists' understanding of water's history and the habitability, or potential, for life. To make this connection, they must know the surface deposits' ages or rates of change.

The density of superimposed large-impact craters allows scientists to estimate the ages of ancient terrains. Younger terrains are lightly sprinkled with only small craters, many of which may be secondary craters formed during larger impacts. Many secondary craters form simultaneously, so they cannot be used to estimate surface age.

Where do we land?

Over the next few years, discussions about where to land the next and most capable rover yet, the Mars Science Laboratory (MSL) will ensue. MRO will be closely involved with this effort on two fronts. First, MRO will provide the final pieces of data needed to determine where it is safe to land. This involves atmospheric data (high near-surface winds are undesirable) and surface science (big rocks and steep slopes are undesirable).

HiRISE can measure boulders down to about 3 feet (1m) wide and 8 inches (20 cm) high and will detect roughness down to scales smaller than 1.5 feet (0.5m). "You want to learn everything you can about the site," says Matt Golombek, co-chair of the MSL landing-site study. "It's one thing to write a science paper that presents a viable working hypothesis. It's another thing to risk a billion-dollar mission on that interpretation," he adds.

Debates rage over where MSL can conduct the best science investigation relevant to the search for life. Some scientists advocate landing in a clay-rich region; others prefer the gullies, while some prefer locations that show signs of long-lived water. MRO is ideally suited to finding a safe location with both structural and mineral evidence for a past habitable environment.

But the most significant results from MRO will be new and unexpected discoveries. As MRO Project Scientist Richard Zurek has said, "Every time we look with increased resolution, Mars has said, 'Here's something you didn't expect. You don't understand me yet.'"

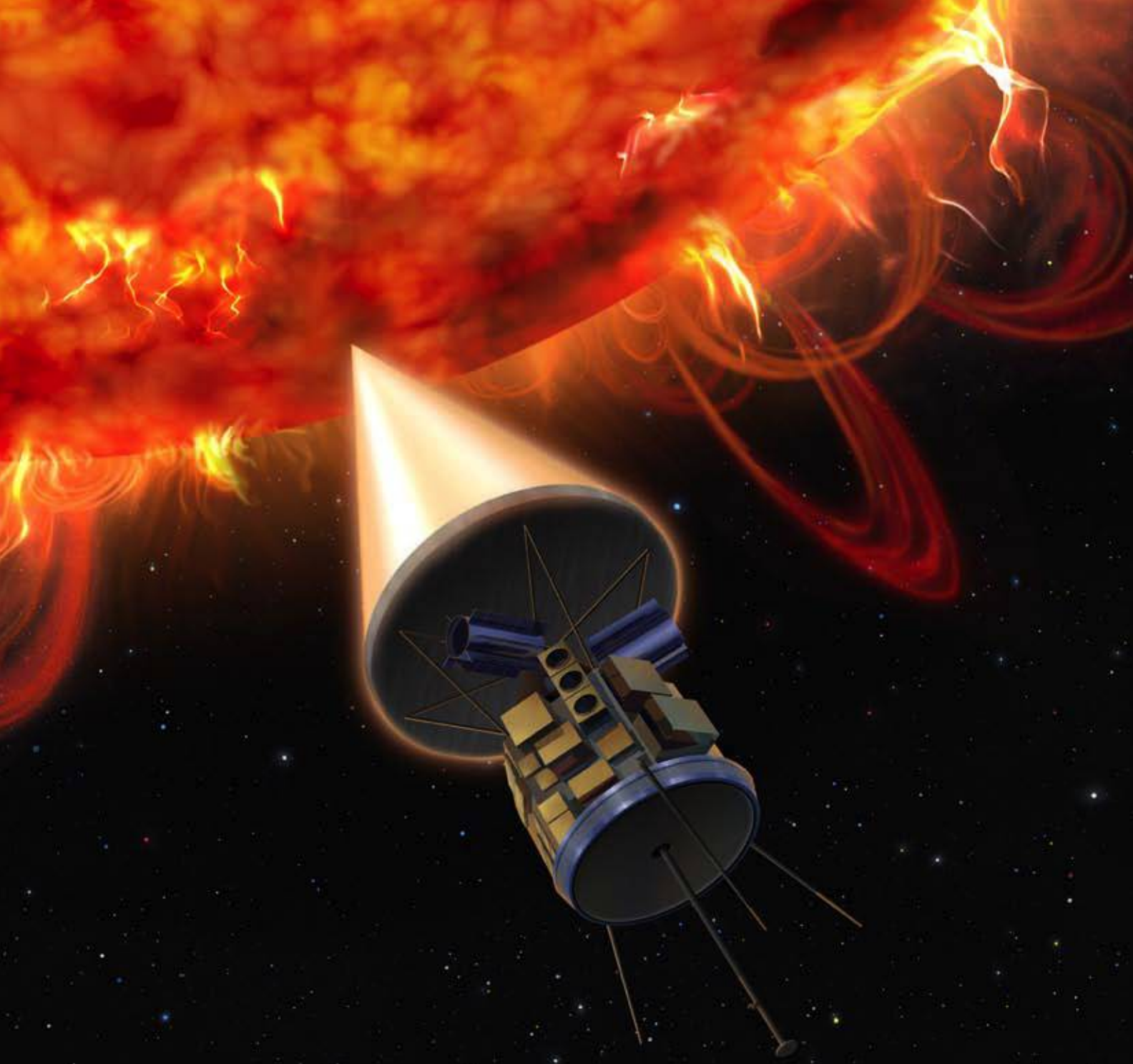
That may be true. But considering the fact that the existence of water canals on the planet was thought possible as recently as the last century, we've come a long way.

MRO'S MARS COLOR IMAGER (MARCI) acquired this seven-band color, wide-angle view of Mars March 24. NASA/JPL/MSSS

THE CONTEXT CAMERA (CTX) took its first image, which shows the east end of Valles Marineris, March 24. NASA/JPL/MSSS

Can we send a spacecraft to the Sun?

NASA's proposed Solar Probe stretches technology and material science to their torrid limits. /// **BY DAVID J. McCOMAS**

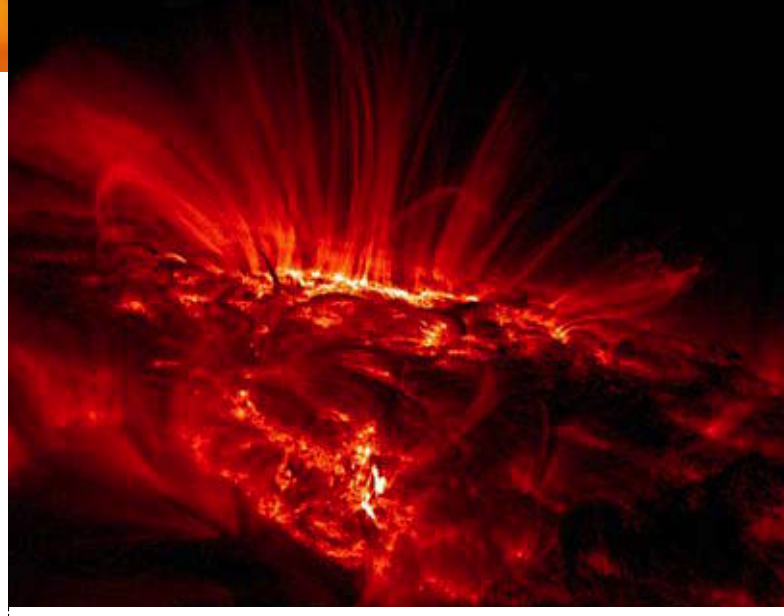


One day — perhaps as early as 2014 — a spacecraft will depart Earth on a voyage of solar exploration. Measuring 8.9 feet (2.72 meters) across and 30.8 feet (9.4m) long, Solar Probe would encounter solar-corona temperatures averaging 3,600,000° Fahrenheit (2,000,000° Celsius) as it passes within 1.3 million miles (2.1 million kilometers) of the Sun's surface.

This mission would answer some of the most vexing questions about our star: What heats the corona (the Sun's outer atmosphere) to millions of degrees? How does the corona transition into the supersonic outflow of ionized gas known as the solar wind?

SOLAR PROBE'S close approach to the Sun will test its thermal-protection system. Here, the glowing cone points toward the Sun and shields the spacecraft's instruments. LYNETTE COOK FOR *ASTRONOMY*

SOLAR ECLIPSES once were the only way to study the Sun's corona. During totality, the Moon covers the solar photosphere (the Sun's visible disk), leaving only its delicate outer atmosphere in view. During the February 26, 1998, eclipse, observers could see inclined streamers and polar plumes. NCAR/HIGH ALTITUDE OBSERVATORY



THIS CLOSE-UP of the Sun's lower corona shows loops of hot plasma traveling along magnetic field lines. Without special equipment (or a total solar eclipse), however, we can't see the corona because it's only one-millionth as bright as the Sun's photosphere. STANFORD-LOCKHEED INSTITUTE FOR SPACE RESEARCH/NASA

To the Sun — finally

The Sun remains our solar system's only unvisited realm, half a century after the Space Age began. We've sent probes to all the planets, and Voyagers 1 and 2 are now exploring the solar system's boundary, the heliosphere. But so far, no mission has gotten close to our star.

Technology finally exists to change that. Consider the immense design challenges for such a spacecraft. It must endure the extreme temperatures and radiation near the Sun. At Solar Probe's planned orbit to within 3 solar radii of the Sun's surface, the spacecraft must endure more than 3,000 times the Sun's heat at Earth's distance.

The space scientists and engineers planning the Solar Probe mission borrowed heat-resistant-material technology from missiles and the space shuttle to fashion a cone-shape thermal-protection system. The cone will shade the spacecraft as it penetrates the solar corona.

This proximity to the Sun will allow revolutionary measurements and images that will greatly expand our knowledge of the corona and solar wind. Solar Probe would make direct, on-the-scene measurements right where the Sun energizes its most hazardous solar particles. The spacecraft also would help us characterize, and even forecast, the changing radiation environment in which future space explorers will work.

Thanks to unprecedented advances in imaging, theory, and modeling, we now know more about the corona and the solar wind than ever before. And yet, solar physics' two fundamental questions remain unanswered. The only way to find out why the corona is so much hotter than the Sun's surface, and how the solar wind accelerates, is to collect data near the Sun.

The Solar Probe mission is rooted in the National Research Council's 2003 decadal survey of solar and space physics. This study stressed the scientific importance of a solar mission and recommended that it be implemented as soon as possible.

In late 2003, NASA formed a Solar Probe Science and Technology Definition Team. The team's official report, issued in September 2005, outlined a $1 billion mission that could launch in about a decade and provide an acceptably low-risk survey of the near-Sun environment. Funding of a mission of this scale will require special congressional appropriations.

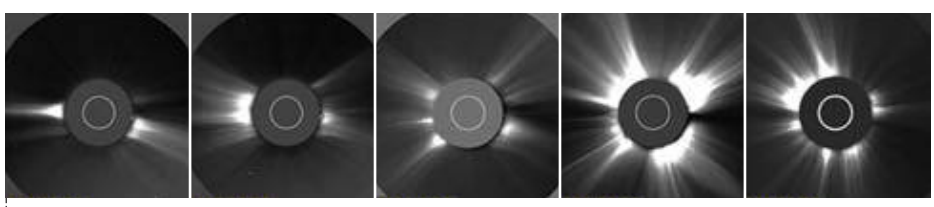
If NASA and Congress fund Solar Probe, it stands to become the first spacecraft to venture into the inner heliosphere, where the solar wind is born. Through direct measurement and imaging of the region's plasma, energetic particles, and fields, Solar Probe would provide the data needed to solve the twin mysteries of coronal heating and solar-wind acceleration.

Keeping Solar Probe cool

At its closest approach to the Sun, Solar Probe will endure solar energy much more intense than at Earth. The design and evaluation of a thermal-protection system (TPS) that will shield the spacecraft in this environment are the central foci of the Solar Probe team's efforts.

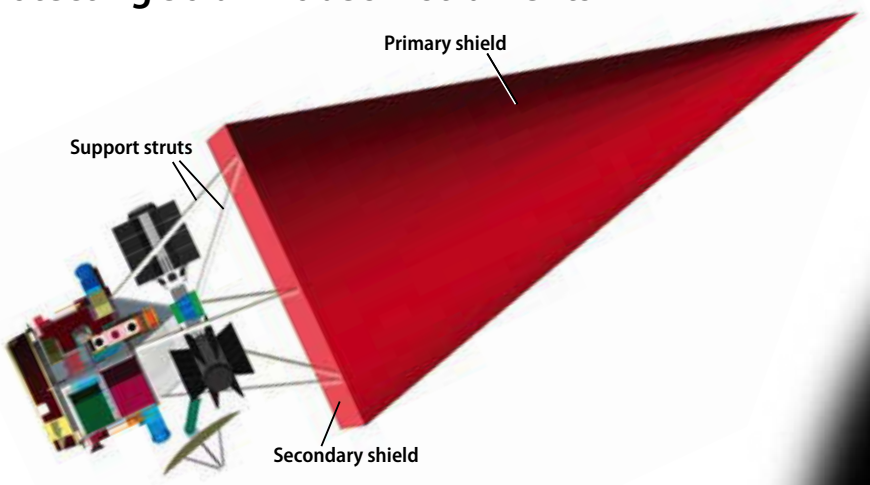
The planned TPS consists of three components. The primary heat shield is a hollow cone about 9 feet (2.7m) in diameter and 17 feet (5.1m) tall made of carbon-carbon composite with a ceramic coating. This shield protects the sensitive instruments and spacecraft subsystems from direct exposure to solar radiation.

David J. McComas *is the senior executive director of the Space Science and Engineering Division at the Southwest Research Institute in San Antonio.*



IMAGES FROM the Solar and Heliospheric Observatory (SOHO) show the corona's evolution during the rising phase of a solar cycle. As activity increases, streamers originate from higher solar latitudes, not just the Sun's equator. SOHO

Protecting Solar Probe's instruments



THIS SCHEMATIC of the Solar Probe spacecraft shows the three main components of the thermal-protection system: the primary and secondary shields and the struts. Engineers constructed each component using a carbon-carbon composite material, which is ultra-heat-resistant.

ASTRONOMY: ROEN KELLY, AFTER JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/NASA

The secondary shield is a disk of carbon-foam layers encased in a carbon-carbon jacket and attached to the primary shield's base. It insulates the instruments from the primary shield, which will reach temperatures approaching 3,000° Fahrenheit (1,650° Celsius) at perihelion (Solar Probe's closest approach to the Sun).

The third component consists of the carbon-carbon attachment struts. They support the TPS and separate it from the spacecraft bus. The separation prevents the secondary shield heat from reaching the bus while providing maximum stability.

Mission scientists conducted thermal analysis using computer models of the TPS, combined with experimental testing of candidate materials. The tests demonstrated the TPS can maintain spacecraft systems at their normal operating temperatures — less than 120° F (49° C) — even during closest approach to the Sun.

During the proposed — and still to be funded — second phase, further testing of TPS materials and components will be performed, and a full-scale prototype will be fabricated, assembled, and tested.

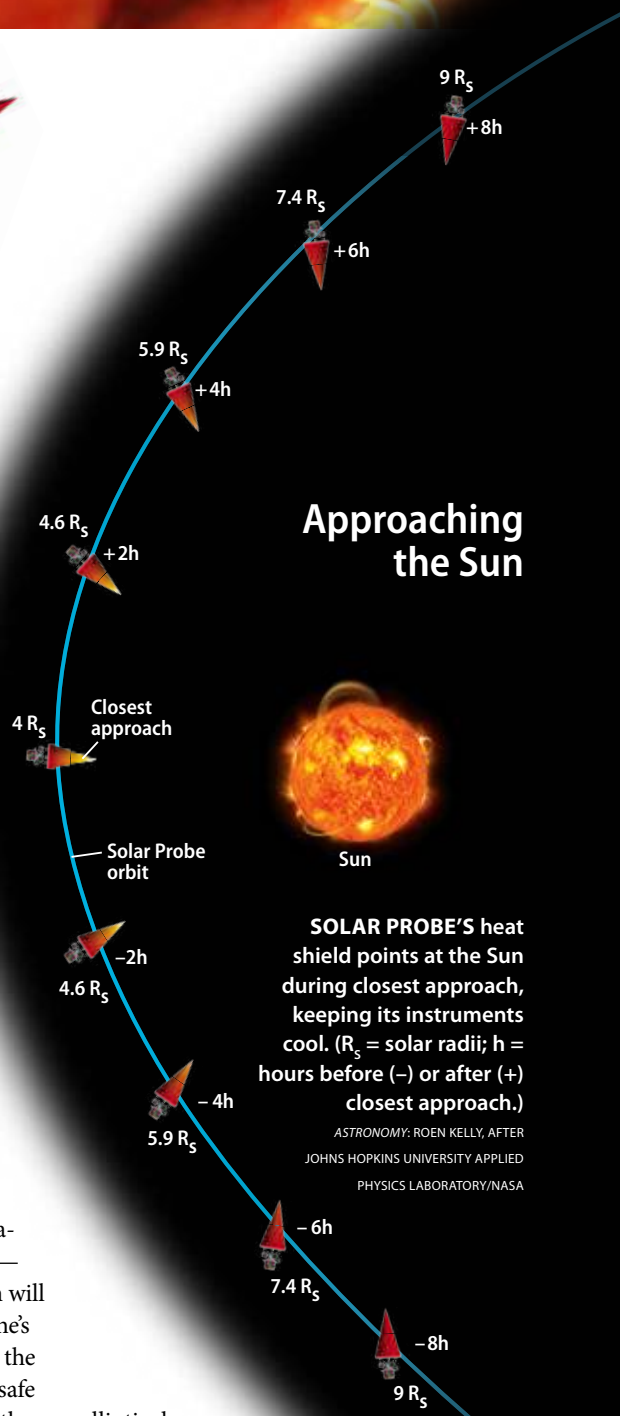
One tough spacecraft

Solar Probe is a gyroscope-stabilized vehicle designed to survive and operate in intense heat. Its most prominent feature is the cone. Twenty days before closest approach, when Solar Probe is near Venus' orbital distance, the craft's thrusters will turn the cone toward the Sun. This provides the protective shadow for the spacecraft bus and instruments. Solar Probe will retain this orientation throughout its encounter.

The instrument package includes instruments both for direct measurement of the solar environment and for remote-sensing observations of coronal structures. Most of the instrument package will be mounted safely inside the heat-protected spacecraft body. Three instruments, however — a fast-ion analyzer, a fast-electron analyzer, and an ion-composition analyzer — will be on a movable arm. This platform will extend instruments out to nearly the cone's edge then retract them incrementally as the spacecraft approaches the Sun and the "safe zone" becomes smaller. Instruments on the arm will gather data just inside the edge of the thermal-protection system's shade. Meanwhile, a retractable, heat-resistant imaging periscope will intermittently poke out beyond the shadow for quick views of the solar wind's source regions.

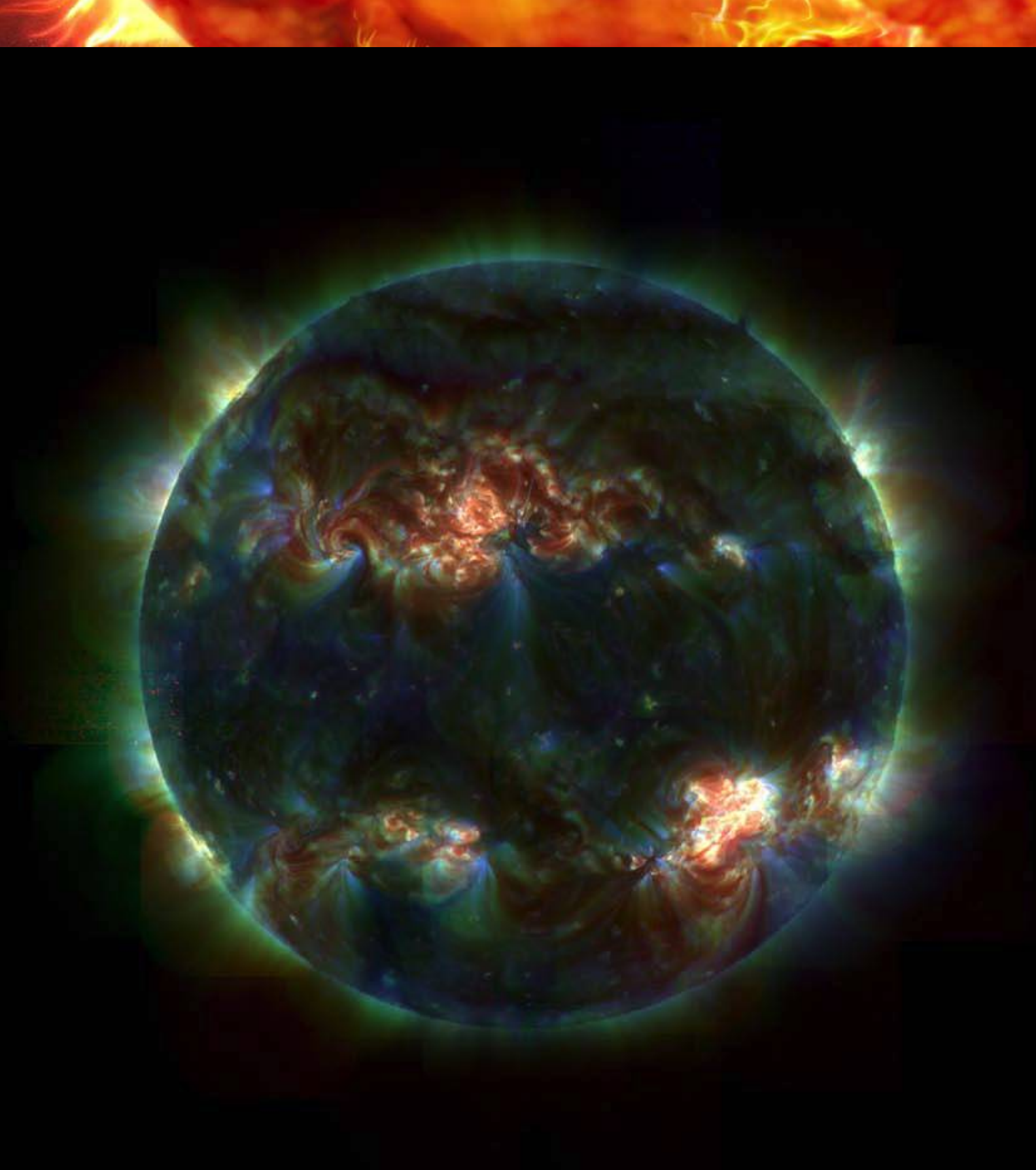
With the trajectory the Solar Probe team has designed, the spacecraft will make two close approaches to the Sun separated by about 4½ years. The first will come as Solar Probe shoots past the Sun's south pole, dives to its closest approach near the solar equator at 670,000 mph (1.09 million kilometers per hour), and then travels outbound over the north pole in a highly elliptical orbit. Even at that speed, the Sun is so large that the spacecraft's pole-to-pole passage takes about 14 hours.

Following its initial pass, Solar Probe will sail out to Jupiter's orbit before the Sun's gravity pulls it back for a return visit along a similar path. These two approaches, and the interval between them, allow the spacecraft to compare solar-wind and coronal measurements during opposite phases of the 11-year solar cycle. (Every 11 years, on average, the Sun



SOLAR PROBE'S heat shield points at the Sun during closest approach, keeping its instruments cool. (R_S = solar radii; h = hours before (–) or after (+) closest approach.)

ASTRONOMY: ROEN KELLY, AFTER JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/NASA



TRACE — the Transition Region and Coronal Explorer spacecraft — currently orbits Earth. TRACE's field of view covers only a fraction of the solar disk, but by repeatedly repointing, it can create an image of the Sun's entire inner corona. This image shows the solar corona on August 2, 1999, in a false-color, 3-layer composite. Imaging revealed the corona at a time when the Sun was moderately active, with some hot (red) active regions in both hemispheres, surrounded by cooler (green and blue) coronal plasma. In contrast to TRACE, which images the Sun from Earth orbit, Solar Probe will provide the first-ever close-up views of the Sun's corona. STANFORD-LOCKHEED INSTITUTE FOR SPACE RESEARCH/NASA

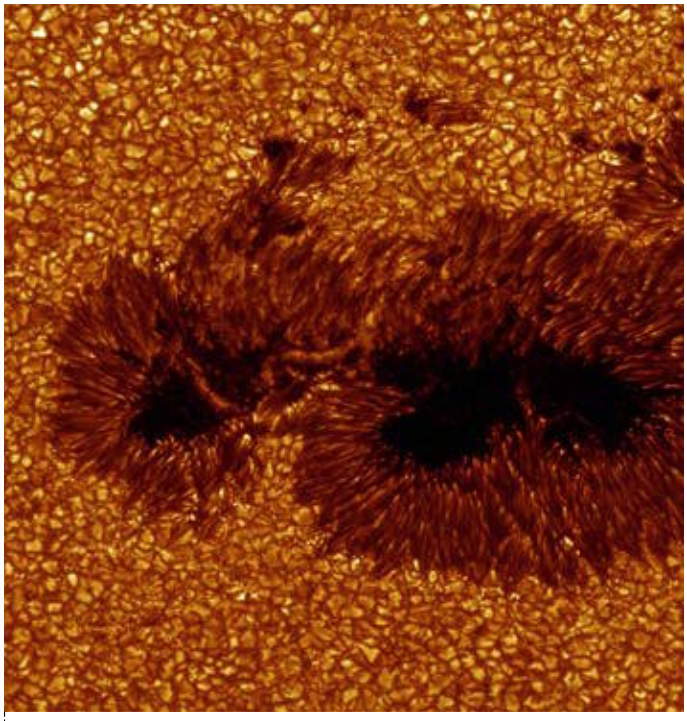
SOLAR PROBE: A LONG TIME COMING

Scientists first recommended the idea of a near-Sun mission in 1958, less than a year after Sputnik awoke the world to the possibilities of sending human-made hardware into orbit and beyond. In that year, the National Academy of Science's Simpson Committee issued recommendations for future missions that the newly organized NASA should undertake. They included sending a spacecraft inside Mercury's orbit to measure the Sun's particles and magnetic fields.

Four years later, the Mariner 2 probe to Venus made the first definitive solar-wind measurements. It confirmed what had been a controversial theory describing the solar corona's supersonic expansion. The next decade saw various missions measure solar-wind properties from different regions of space — but none ventured inside Venus' orbit.

In the mid-1970s, the joint U.S.-German Helios project placed two spacecraft into highly elliptical orbits that ventured a little closer to the Sun than Mercury. These data remain the closest measurements of the Sun. But their closest approach was 60 solar radii — far outside the corona and the region where solar-wind acceleration occurs.

Since then, as new heat-shield materials and spacecraft propulsion systems were developed, NASA conducted several solar-mission studies. Some manner of solar probe has remained consistently at or near the top of various National Science Academy and NASA priority lists. One short-lived plan even proposed a joint U.S.-Russian mission in the 1990s. — *D. J. M.*



THE SUN'S PHOTOSPHERE, or visible surface, is the region we're most familiar with. Only the best solar telescopes, however, deliver an image like this one. Besides sunspots, dark areas roughly 3,000° F (1,650° C) cooler than the surface, the telescope also resolved granules, the tops of convective plasma-current cells. G. SHARMER AND K. LANGHANS, INSTITUTE FOR SOLAR PHYSICS OF THE ROYAL ACADEMY OF SCIENCES, SWEDEN

moves from one period of high activity to the next.) For example, if Solar Probe launches in 2014, its first flyby will take place in 2018, around the solar minimum. The second flyby, in 2023, will occur during a time of increased solar activity.

Why we need to get close

Thanks to years of observations coupled with complex modeling and sophisticated theoretical research, scientists already have a general picture of how the Sun's corona and the solar wind operate. They know that at times of lower solar activity, the solar wind has two components: a dominant, steady, high-speed wind and a more variable, low-speed wind. Each emanates from specific coronal zones.

As solar activity increases to solar maximum, this orderly configuration breaks down into a complex mixture of fast and slow winds from all areas of the corona. The energy that heats the corona and drives the wind manifests itself as motions of plasma within and around the Sun. Magnetic fields channel, store, and then dissipate these plasma motions. Heliophysicists believe waves, instabilities, magnetic reconnections, and turbulence — all operating on vast scales — play roles in coronal heating and solar-wind acceleration.

Scientists now want to know the geometry and dynamics of the expanding magnetic fields and particle distributions that lie at the sources of the fast and slow solar winds. Solar Probe will trace the energy flow that heats the corona and accelerates the solar wind. It also will determine what mechanisms accelerate and transport these charged particles around the Sun.

As a bonus, Solar Probe's unique path close to the Sun will answer some questions about the size and mass distribution of mysterious dust grains orbiting near the Sun. This dust, believed to originate from comets and asteroids, interacts with the corona and may influence the solar wind and the formation of energetic particles.

Finally, even though Solar Probe will go where humans cannot, what scientists learn from the mission will play an important role in piloted missions to the Moon and Mars. On these expeditions (well beyond the protective shield of Earth's magnetic field), astronauts may be exposed to intense blasts of the Sun's energetic particles. Such events present serious threats to humans living and working beyond Earth.

Solar Probe will make the first direct measurements of the near-Sun region, sample the environment where solar plasma particles are energized, and identify the seed populations for these dangerous particles. The spacecraft also will provide critical data for predictive models that — along with solar and heliospheric monitoring — will enable scientists to forecast the space-radiation environment in support of human exploration.

Solar Probe's visit to a never-before-explored region of our solar system will answer questions that simply can't be answered any other way. The answers will help space scientists understand what's going on in a region that has awed and frightened humans since we first witnessed the Sun's beautiful and mysterious corona during a total eclipse.

Moreover, as with any voyage into uncharted territory, Solar Probe's journey also holds the promise of unanticipated discoveries — new mysteries that will challenge humanity's ever-expanding knowledge of our home in the universe. A

ONLINE EXTRA See a Solar Probe animation at www.astronomy.com/toc.

BY MARTIN RATCLIFFE AND ALISTER LING

DECEMBER 06

Mercury greets Jupiter and Mars

Now's the time to catch Mercury showing off.

It shines brightly against the deep-orange glow of the approaching day and should be a snap to find around 6 A.M. local time, an hour before sunrise. The innermost planet has a well-earned reputation for quickly disappearing off the stage, however; so don't wait long.

Early risers receive a wonderful bonus when the giant planet Jupiter soars past sinking Mercury. By December 7, blazing Jupiter should be easy to spot as long as you have an unobstructed southeastern horizon. Make sure you take a look through binoculars — you'll find Mars hiding between the pair. Far from its glory at opposition, Mars lies on the far side of the Sun from Earth and glows feebly, two full magnitudes fainter than Mercury.

Closest approach for the two bright planets comes the morning of December 10 at about noon EST, when Mercury skims just 8', one-quarter the Moon's apparent diameter, past Jupiter. If your telescope can track, follow the pair from dawn right through the day.

Ringed Saturn rises in the east before 10 P.M. by mid-December. It shines with a steady yellow glow compared with the twinkling stars commanding the southern sky. Unfortunately, turbulence in Earth's atmosphere degrades Saturn's image through a telescope when the planet lies close to the horizon. Your best views will come near dawn. Avoid looking over chimneys now that heating season is in full swing.

JUPITER, MARS, AND VENUS GATHERED

November 15, 1995 (in that order, top to bottom). Mercury swaps with Venus in a similar conjunction this month. KEN REJKO/GLENN SMITH

December means it's Geminid time. Relatively slow but bright shooting stars are the trademarks of winter's best meteor shower, which hits its peak the morning of the 14th. If it weren't for the cold, many observers would rank the Geminids ahead of August's Perseids for oohs and aahs. Bundle up, and prepare to awake just before dawn, when rates are highest. Observing in the early evening, and especially from the city, will prove disappointing because half the meteors occur below the horizon, and another big chunk is lost behind the veil of light pollution. The waning crescent Moon will interfere some, but not enough to spoil the show. Many observers go with a group to a dark site — the experience can be a lot of fun.

The Moon covers the Pleiades star cluster (M45) twice this month. The first time comes the evening of December 3, although some guide books and calendars list it on the 4th, in Universal Time (UT). Astronomers use UT to avoid the confusion that arises from different time zones. It runs 5 hours ahead of EST.

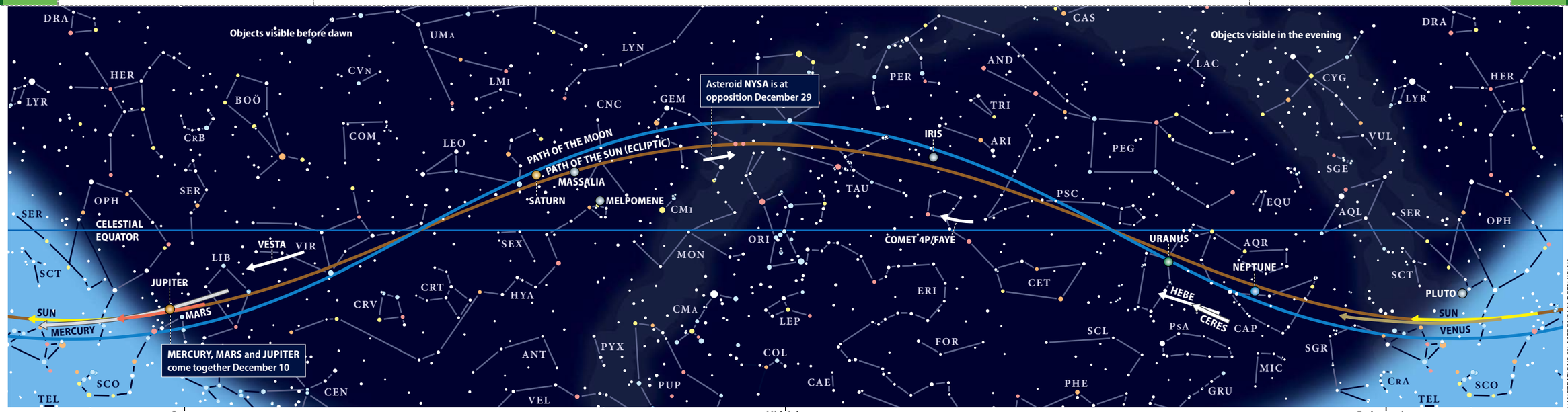
Because the Moon appears just before full on the 3rd, stars will disappear behind a slim, dark limb. An hour or 2 later, they reappear against the Moon's bright limb — a much tougher observation. You can find precise occultation times for many individual Pleiads from most cities on the web at lunar-occultations.com/iota.

The Moon's second Pleiades passage occurs the morning of December 31. It can be seen from North America's West Coast (just before dawn), the Pacific Ocean, and eastern Asia.

Have you missed Venus recently? It's been on the far side of the Sun from Earth, but it's coming back to reclaim its title as the evening star. Just before New Year's, Venus starts poking through the bright yellow sky shortly after sunset. Use binoculars to find it initially. In just a few days, however, it will be obvious to the unaided eye. It's heading for a marvelous conjunction with the Pleiades in mid-April.

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

[21] [20] [19] [18] [17] [16] [15] [14] [13] [12] [11] [10] [09] [08] [07] [06] [05] [04] [03] [02] [01]

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

[31] [30] [29] [28] [27] [26] [25] [24] [23] [22] [21] [20] [19]

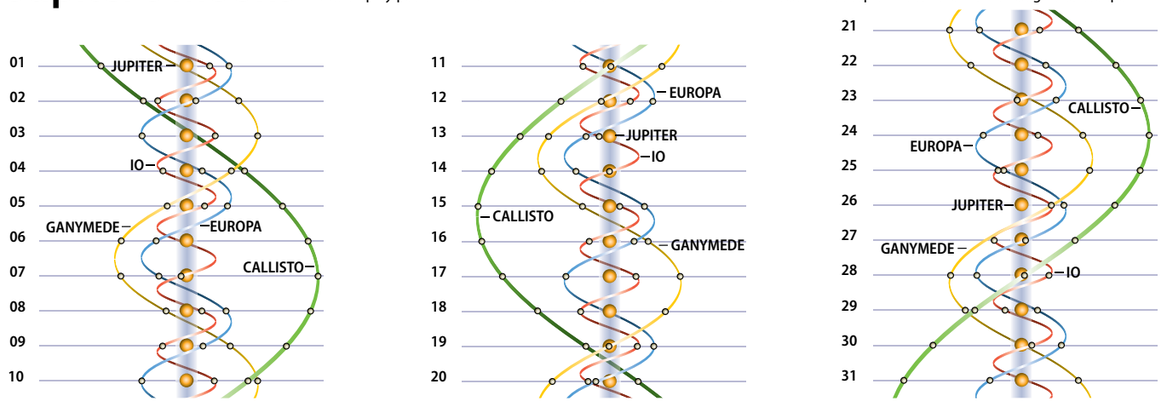
PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	December 1	December 15	December 15	December 15	December 15	December 15	December 15	December 15	December 15
Magnitude	−0.7	−0.8	−3.8	1.5	−1.7	0.4	5.9	7.9	14.0
Angular size	6.0"	5.0"	10.0"	3.8"	31.3"	19.2"	3.5"	2.2"	0.1"
Illumination	76%	94%	98%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.129	1.347	1.662	2.454	6.296	8.673	20.265	30.608	32.187
Distance (AU) from Sun	0.376	0.444	0.728	1.537	5.370	9.174	20.087	30.051	31.212
Right ascension (2000.0)	15h11.2m	16h33.8m	18h20.3m	16h16.9m	16h10.7m	9h50.3m	22h50.9m	21h20.2m	17h44.7m
Declination (2000.0)	−15°47'	−21°39'	−24°12'	−21°27'	−20°21'	14°18'	−8°10'	−15°47'	−16°29'

10"

S W E N

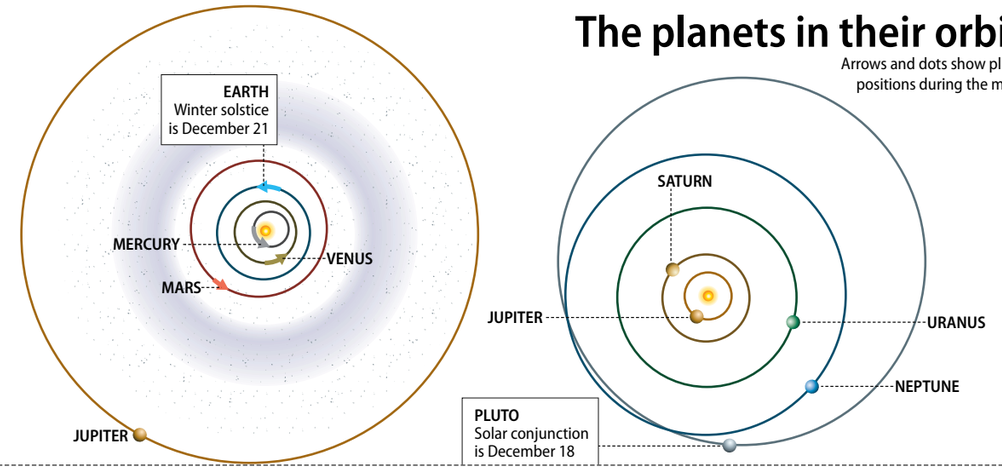
Jupiter's moons

Dots display positions of Galilean satellites at 7 A.M. EST on date shown. South is at top to match the view through a telescope.



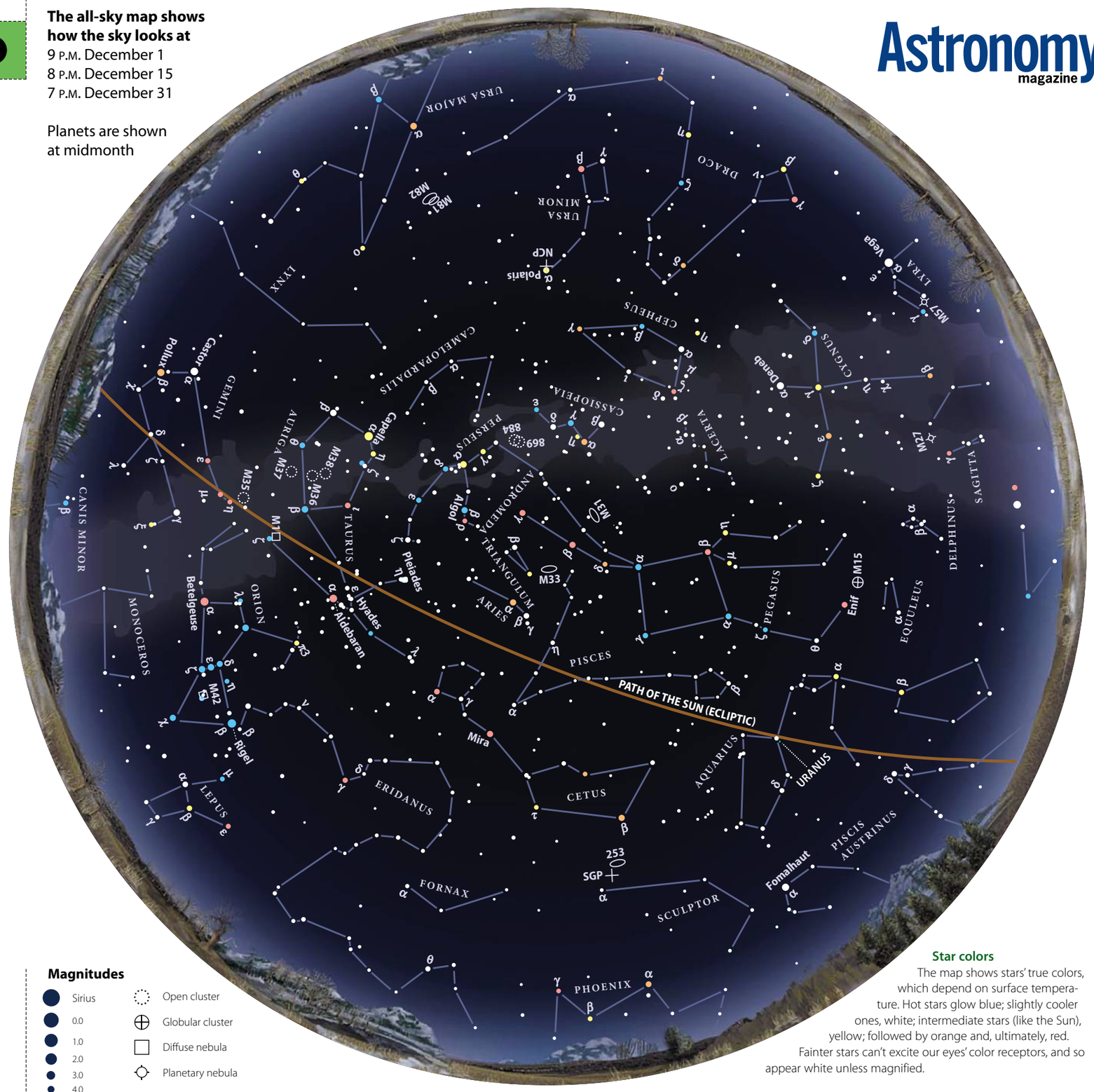
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
9 P.M. December 1
8 P.M. December 15
7 P.M. December 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors

The map shows stars' true colors, which depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

december 06

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					[01]	[02]
[03]	[04]	[05]	[06]	[07]	[08]	[09]
[10]	[11]	[12]	[13]	[14]	[15]	[16]
[17]	[18]	[19]	[20]	[21]	[22]	[23]
[24]	[25]	[26]	[27]	[28]	[29]	[30]
[31]						

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 The Moon is at perigee (227,374 miles from Earth), 7:06 P.M. EST

04 Full Moon occurs at 7:25 P.M. EST

10 The Moon passes 1.2° north of Saturn, 6 A.M. EST

Mercury passes 0.1° north of Jupiter, 11 A.M. EST

11 Mars passes 0.8° south of Jupiter, 7 P.M. EST

12 Last Quarter Moon occurs at 9:32 A.M. EST

13 The Moon is at apogee (251,294 miles from Earth), 1:55 P.M. EST

14 Geminid meteor shower peaks

15 The Moon passes 0.8° south of Spica, 6 A.M. EST

18 Pluto is in conjunction with the Sun, 10 A.M. EST

The Moon passes 6° south of Jupiter, 4 P.M. EST

Mars passes 4° north of Antares, 10 P.M. EST

The Moon passes 5° south of Mars, 11 P.M. EST

20 New Moon occurs at 9:01 A.M. EST

21 Winter solstice occurs at 7:22 P.M. EST

25 The Moon passes 0.08° north of Uranus, 4 P.M. EST

27 First Quarter Moon occurs at 9:48 A.M. EST

The Moon is at perigee (230,108 miles from Earth), 9:19 P.M. EST

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

THE DEEP SKY

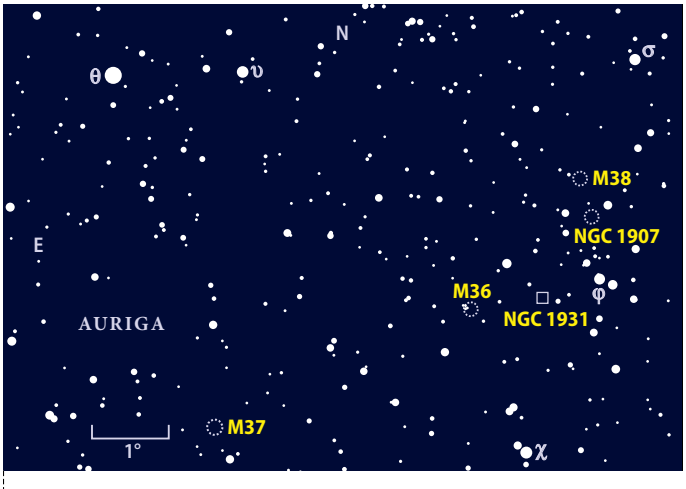
Ride the chariot's stellar riches

Although summer's Sagittarius possesses many of the sky's biggest and brightest deep-sky objects, winter's Auriga has a sparkling vista unrivaled elsewhere. There's no better way to view this magnificent region than through binoculars. You can find Auriga's stretched pentagon shape climbing in the northeast as darkness falls. It's suspended under the twinkling yellow luminary Capella.

Binoculars provide just the right magnification to show fields overflowing with bright stars immersed in a faint but rich Milky Way background. As many of you know, a dark sky away from light pollution and moonlight will give you the best return for your effort.

Three bright star clusters jump out from the hundreds of faint background stars. Smack in the center of Auriga's pentagon lies Messier number 38. Steadily held binoculars capture the brighter pinpoints of this celestial star-city. In the same field, the brighter cluster M36 probably has caught your attention as well. If you shift your sight 4° more to the east — still in the same field as M36 — the softer glow of M37 betrays its presence. If you lose your way, try aiming halfway between Theta (θ) Aurigae and Beta (β) Tauri, then ease a bit east. Sky directions can be confusing. Remember, from the Northern Hemisphere in mid-evening, east in Auriga means to the lower left.

Use a telescope to uncover the different faces of these three star clusters. M37 contains the faintest stars, and they're all nearly identical except for the central orange-hued luminary. M36 holds mostly bright stars, with some decked out in pairs. In contrast, M38 has stars that run the gamut of magnitudes. If you have a 6-inch or bigger scope, check out M38's nice companion cluster, NGC 1907, just south of M38.



AURIGA PACKS MANY STAR CLUSTERS
within its borders. The three Messier clusters — M36, M37, and M38 — stand out from their Milky Way neighbors. *ASTRONOMY:* ROEN KELLY

NOAO/AURA/NSF

OPEN STAR CLUSTER M37 IN AURIGA
contains 200 stars in a 27-light-year diameter. Despite lying 4,600 light-years away, it shines bright enough to see with naked eyes.

Heart stopper

A few lucky amateur astronomers have discovered comets accidentally while searching for deep-sky objects. Tucked among the star clusters in Auriga lurks a comet look-alike that has startled more backyard observers than any other. Unlike galaxies and faint star clusters, the combination emission and reflection nebula NGC 1931 makes a good fake through a small scope operating at low power.

The masquerade begins with a bright, diffuse head, and enchants us further with a fan-shape tail of nebulosity — just like many comets. But the excitement soon dies. Comets drift during a night's observing session, while background objects remain fixed.

A nebula filter does not enhance NGC 1931 because its glow comes mainly from scattered starlight and not fluorescence. As a result, you'll have a tough time enjoying the view from a city, if you're able to find NGC 1931 at all.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

THE PLANETS

Three planets come together at dawn

Venus returns to the evening sky in late December, and Uranus remains an easy binocular object after dusk. Saturn joins the parade later in the evening, when it rises in the east. But the month's best planetary event occurs in the predawn sky: Jupiter, Mars, and Mercury lie within a 1° patch of sky December 10. Those lucky enough to have 3 or more clear mornings in a row will be able to watch the trio's rapidly changing appearance.

You'll have a hard time tracking down **Venus** in early December, but by month's end, it appears clearly after sunset. On December 18, the brilliant planet stands a mere 3° above the southwestern horizon 30 minutes after sunset. By the end of the year, it rises to 6°.

Venus now lies on the far side of the Sun from Earth. As a result, telescopic views show a fully illuminated disk that spans a meager 10". As the planet's orbit carries it closer to Earth over the next several months, you'll be able to see Venus' disk increase in apparent size while the illuminated portion shrinks.

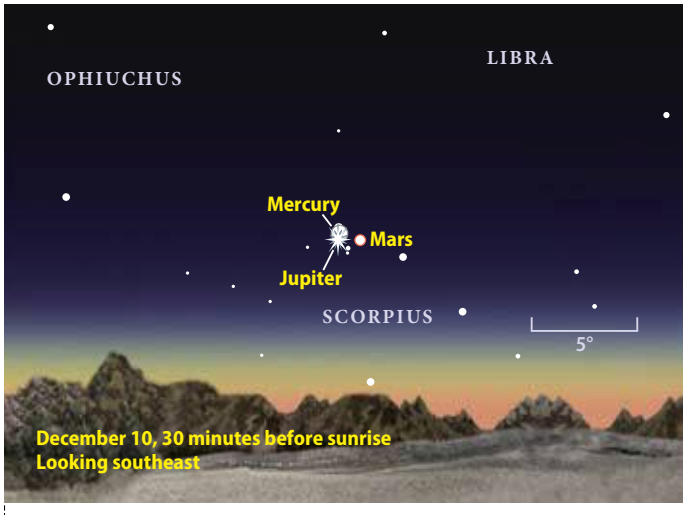
Neptune and **Uranus** hang in the southwest after darkness falls. Neptune's lower altitude and fainter glow make it troublesome to spot. But December offers a last good look at Uranus before it becomes lost in twilight. Its higher altitude and brighter disk bring it within easy range of binoculars. The 6th-magnitude planet lies in Aquarius, less than 1° below 4th-magnitude Lambda (λ) Aquarii. By December 31, Uranus is less than 1 Moon-width south of the star.

By late evening, you can find **Saturn** climbing in the east among the stars of Leo the Lion. On December 9, a waning gibbous Moon rises with Saturn around 10 P.M. local time. A mere 3° separate the two solar system objects. During the morning hours, this distance shrinks to just 1°. Regulus, Leo's 1st-magnitude luminary, lies 5° from Saturn.

The ringed planet begins its retrograde loop December 6. On this date, it starts moving westward relative to the background stars. It approaches within 4.8° of Regulus on the 6th and then starts creeping away during the rest of the month. This retrograde motion means Earth, in its faster, inner orbit around the Sun, has started to overtake Saturn. It foretells the planet's upcoming opposition in February.

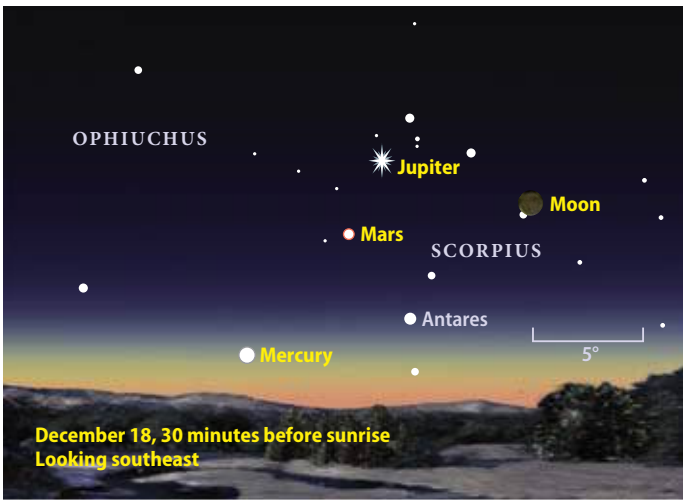
The best views of Saturn through a telescope will come well after midnight, once the planet has climbed far above the horizon. At December's close, the ringed planet stands 35° high in the east by midnight local time.

Saturn's magnificent rings span 43" through their long axis and 9" through their short axis. With the minor axis now slightly less than half the 19" diameter of Saturn's globe, details in Saturn's atmosphere should be easier to view than they have been the past few years. Still, these atmospheric features remain subtle at best.



ASTRONOMY: ROEN KELLY

THREE PLANETS APPROACH WITHIN 1°
before dawn December 10. Mercury, Mars, and Jupiter are closer then than any three naked-eye planets will be for 47 years.



THE MORNING PLANETS MOVE APART
by the 18th, but the addition of a crescent Moon and Mars' near twin, Antares, keeps the scene exciting. ASTRONOMY: ROEN KELLY

Saturn's brightest moons offer a range of challenges for backyard observers. Titan, the ringed planet's biggest moon, is also its brightest, glowing at magnitude 8.4. It's easy to spot through any size telescope. As the moon's light falls on your retina, remember this is the most distant object on which humans have landed a spacecraft (the Huygens probe in January 2005). Titan completes one orbit of Saturn every 16 days. You can find it due north of Saturn the mornings of December 3 and 19, and due south of the planet the mornings of December 11 and 27.

Iapetus lies at the fainter extreme. It also varies in brightness, appearing 5 times brighter when farthest west of Saturn than when farthest east. Iapetus reaches greatest eastern elongation December 18, and its 11.9-magnitude glow will be tough to pick up.

Although Saturn's other bright moons won't be as hard to see, they do hover like fireflies close to Saturn's brilliant glare. The three easiest inner moons to locate are Tethys (magnitude 10.3), Dione (10.4), and Rhea (9.7). You'll need superb conditions to spot 12th-magnitude Enceladus and 13th-magnitude Mimas.

Jupiter, **Mercury**, and **Mars** have a spectacular and rare close conjunction in the morning sky December 10. This month also continues Mercury's best morning apparition of the year. On December 1, the innermost planet shines at magnitude –0.7 and stands 8° high in the east-southeast 45 minutes before sunrise.

During the following week, Mercury sinks in the predawn sky while dim Mars and brilliant Jupiter climb higher, setting up a grand meeting against the background stars of Scorpius. On December 9, the three planets form a neat triangle in the twilight 45 minutes before sunrise. Mercury then stands 1.5° west of Jupiter and 1° north of Mars.

The following morning, Mercury and Jupiter lie just 17' apart and appear in the same telescopic field of view. The pair sits just below Beta (β) Scorpii, a 2.5-magnitude double star that will be difficult to see in the twilight, and 1° to Mars' left. This marks the closest conjunction of three naked-eye planets during the first half of the 21st century.

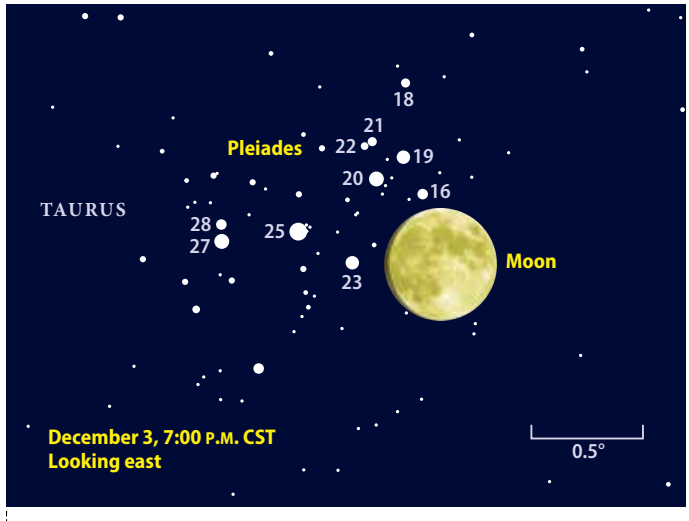
On December 11, Mercury scoots a degree below Jupiter, and the two form another triangle with Mars. Only 48' separate Mars and Jupiter. With each day, Jupiter gains altitude in the morning sky and becomes easier to see, while Mercury falls and becomes more difficult to spot.

The morning of December 18 finds a slim crescent Moon 7° to the right of Jupiter, and Mercury 10° to the lower left of Jupiter. Mars then lies about halfway between these two planets. Look carefully, and you should see 1st-magnitude Antares, the brightest star in Scorpius, 4° to Mars' lower right. The ruddy star's light should closely match the Red Planet, which shines half a magnitude fainter.

On December 3, North American observers have the chance to see a nearly Full Moon pass in front of the Pleiades star cluster (M45). The first occultation of a Pleiad occurs soon after dark. Although the Moon doesn't have much of a dark limb this night, it leads the way, so viewers with telescopes should have little trouble seeing stars disappear. Viewing reappearances at the bright limb is much harder. European observers see the same event the morning of December 4.

A similar occultation occurs December 31 for those living along the Pacific Rim. You can find precise occultation times for many cities on the International Occultation Timing Association's web site (lunar-occultations.com/iota).

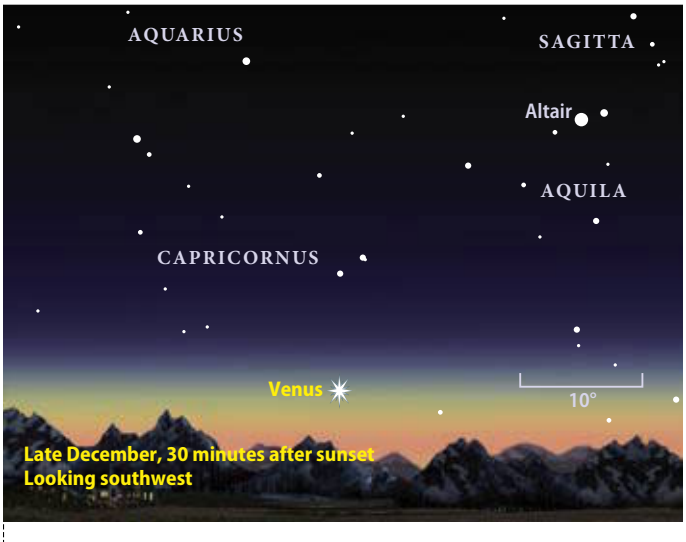
The Sun reaches its farthest point south in our sky this month. Winter in the Northern Hemisphere officially begins December 21 at 7:22 P.M. EST.



ASTRONOMY: ROEN KELLY

THE MOON TRAVERSES THE PLEIADES

the evening of December 3. Observers will need telescopes to see individual stars wink out along the nearly Full Moon's dark limb.



VENUS RETURNS TO THE EVENING SKY

this month after an 11-month hiatus. You can find the brilliant planet low in the southwest shortly after sunset. *ASTRONOMY*: ROEN KELLY

METEORS AND MOONS

A double dose of meteors

One of the strongest meteor showers of the year peaks the morning of December 14. The Geminids can produce around 100 meteors per hour from a dark site when the radiant lies overhead. And the radiant, in the constellation Gemini the Twins, passes nearly overhead around 2 A.M. local time. North American observers will have the best view this year because astronomers expect the shower to peak around 6 A.M. EST.

A waning crescent Moon rises with the constellation Virgo between 1 A.M. and 2 A.M. local time. Although the Moon provides some interference, the stray light shouldn't be more than a minor nuisance. Geminid meteors strike Earth's atmosphere at 22 miles per second, modest by meteor standards, and tend to be bright. The Geminid shower compares favorably with August's Perseids, particularly this year, when a nearly Full Moon hampered Perseid viewing. Possible cold temperatures remain the Geminids' chief drawback. To enjoy Geminid observing to the fullest, dress warmly and bring along a hot beverage.

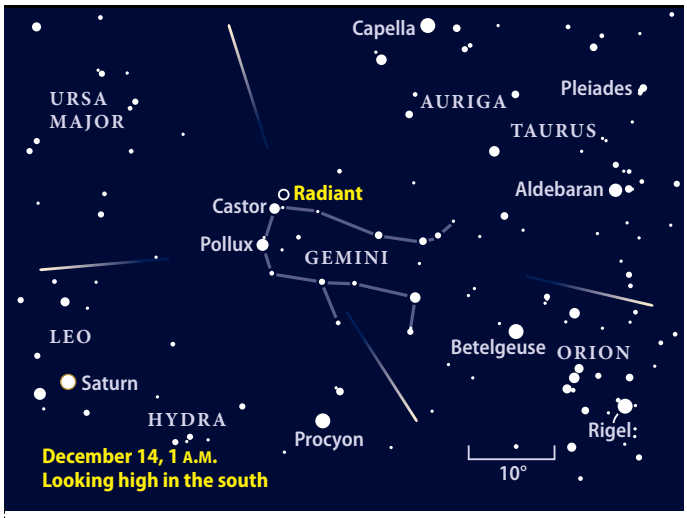
A second meteor shower peaks about a week later, on December 22, when the Moon doesn't interfere at all. The Ursids don't boast the same numbers as the Geminids; the former averages no more than 10 meteors per hour in a typical year. But occasional outbursts, which raise the rate to around 50 per hour, do occur. Ursid meteors are a tad slower than Geminids and tend to be faint.

The Ursid shower's radiant lies in Ursa Minor, near the bright star Kochab (Beta [β] Ursae Minoris). This region is circumpolar from most of the Northern Hemisphere, so viewing can last all night. Like most meteor showers, however, rates improve after midnight.

A prime lunar crater

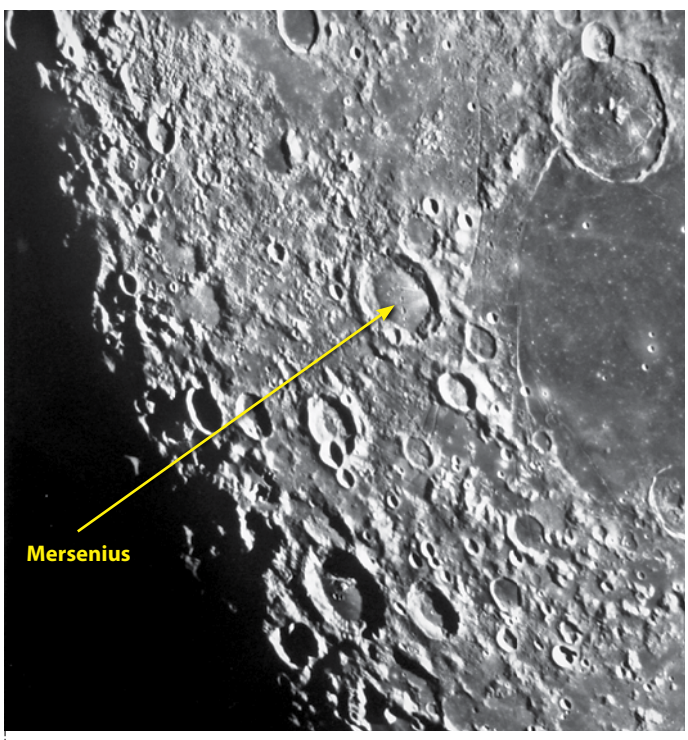
Southwest of the Moon's prominent crater Gassendi, on the western shore of Mare Humorum, lies the 52-mile-wide crater Mersenius. Through a small telescope, the lava-filled Mersenius shows a clearly defined rim. Several smaller craters pepper the main crater's rim and attest to its great age. As the Sun rises over Mersenius, as it does both December 1 and 31, you should be able to see that the floor bulges upward. You also may notice a string of small craters pitting the floor. One thing you won't see in Mersenius is a central mountain peak.

A long rille stretches along the eastern side of Mersenius and to its south. Most other nearby rilles appear to be concentric with the Humorum basin, but the Mersenius rille is not. This deviation hints at a different origin. Charles Wood, in his book *The Modern Moon*, suggests this rille runs radial to Oceanus Procellarum and may have formed in response to the giant impact that created this great basin.



ASTRONOMY: ROEN KELLY

THE BEST METEOR SHOWER OF 2006, the Geminids, peaks the morning of December 14. Attentive observers may see up to 100 meteors per hour.



FROM *CONSOLIDATED LUNAR ATLAS* (UA/LPL)

WITH A BULGING, LAVA-FILLED FLOOR, the lunar crater Mersenius cuts a distinctive profile on the western shore of Mare Humorum. A small scope will reveal its wonders.

Asteroid Iris glows brightly

Most main-belt asteroids orbit the Sun in roughly the same plane as the planets. As a result, they never stray far from the ecliptic (the brown curved line on the circular all-sky map at the magazine's center). The Moon's orbit tilts 5° from the ecliptic, so our satellite also stays relatively nearby. By coincidence, this month, the Moon passes in front of the brightest asteroid in the sky, 7 Iris, not far from the Pleiades star cluster.

Why should you be awake at 4 A.M. EST December 3 to watch? One reason is the asteroid disappears behind the Moon's limb more gradually than the instantaneous vanishing act of a star. You can see for yourself if you live south of a line stretching from Washington State to North Carolina, because the Moon almost simultaneously occults the bright double star Epsilon (ε) Arietis. Along this graze line, you'll see many events as the star peeks through lunar valleys. Head to lunar-occultations.com/iota for details.

Epsilon Ari serves as a guidepost for tracking the slow nightly motion of 130-mile-wide Iris. It may take a few nights of binocular observing before you notice the asteroid's movement (wait a few days until the Moon gets out of the way). By the way, a good 4-inch scope should be able to split this double star. The components shine at magnitudes 5.2 and 5.5, with a tight, 1.5" gap between them.

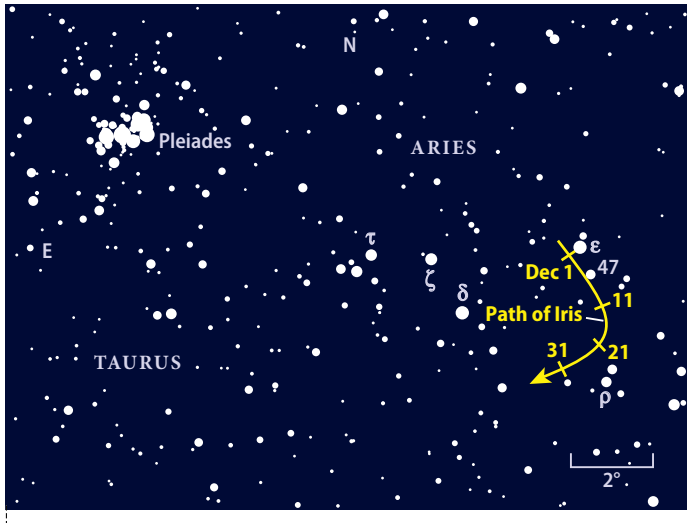
Faye thee well

Because Comet 4P/Faye swings no closer to the Sun than the orbit of Mars, it rarely gets brighter than 8th magnitude. Unlike this past spring's Comet 73P/Schwassmann-Wachmann 3, which was full of surprises as it broke into dozens of pieces, Faye should behave like a typical dirty snowball. The inner part of Faye's orbit lies close to Mars', and the two objects share similar characteristics as they move across the sky.

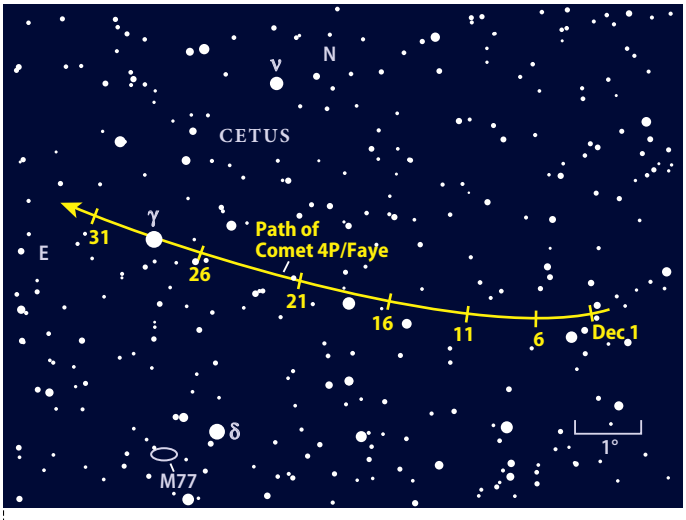
Faye reached opposition in late October, so it now appears in the southeast once the sky grows dark. It travels more slowly than Earth, but doesn't fall behind that quickly. This means it will hang around for a few more months, moving eastward against the background stars.

You can find Faye in Cetus, to the west of Aldebaran (right, as seen from the Northern Hemisphere). The celestial whale is not an easy constellation for newcomers to picture. Try anchoring yourself to the three brighter stars of the tail and working from there. Not far from Delta (δ) Ceti, you'll find M77, the nearest Seyfert galaxy to us. The main difference between a normal galaxy like the Milky Way and a Seyfert is that the supermassive black hole at the Seyfert's center actively swallows material, and the accretion disk that forms around this black hole emits lots of energy. Comet Faye should appear about a magnitude fainter than M77.

A waxing gibbous Moon passes near Faye December 29 and will try to cast a shroud over an interesting event. The comet then passes in front of the bright double star Gamma (γ) Ceti, whose components shine at magnitudes 3.5 and 7.3 and lie a fairly tight 2.8" apart. Will Faye's sunlit dust cocoon completely hide the stars, or will they look like extra false nuclei?



ASTEROID IRIS CROSSES EASTERN ARIES
this month, not far southwest of the Pleiades star cluster. A nearly Full Moon occults the asteroid the morning of December 3.



NINTH-MAGNITUDE COMET 4P/FAYE
heads east through Cetus this month. It should look similar to, if a bit fainter than, the nearby Seyfert galaxy M77. *ASTRONOMY:* ROEN KELLY

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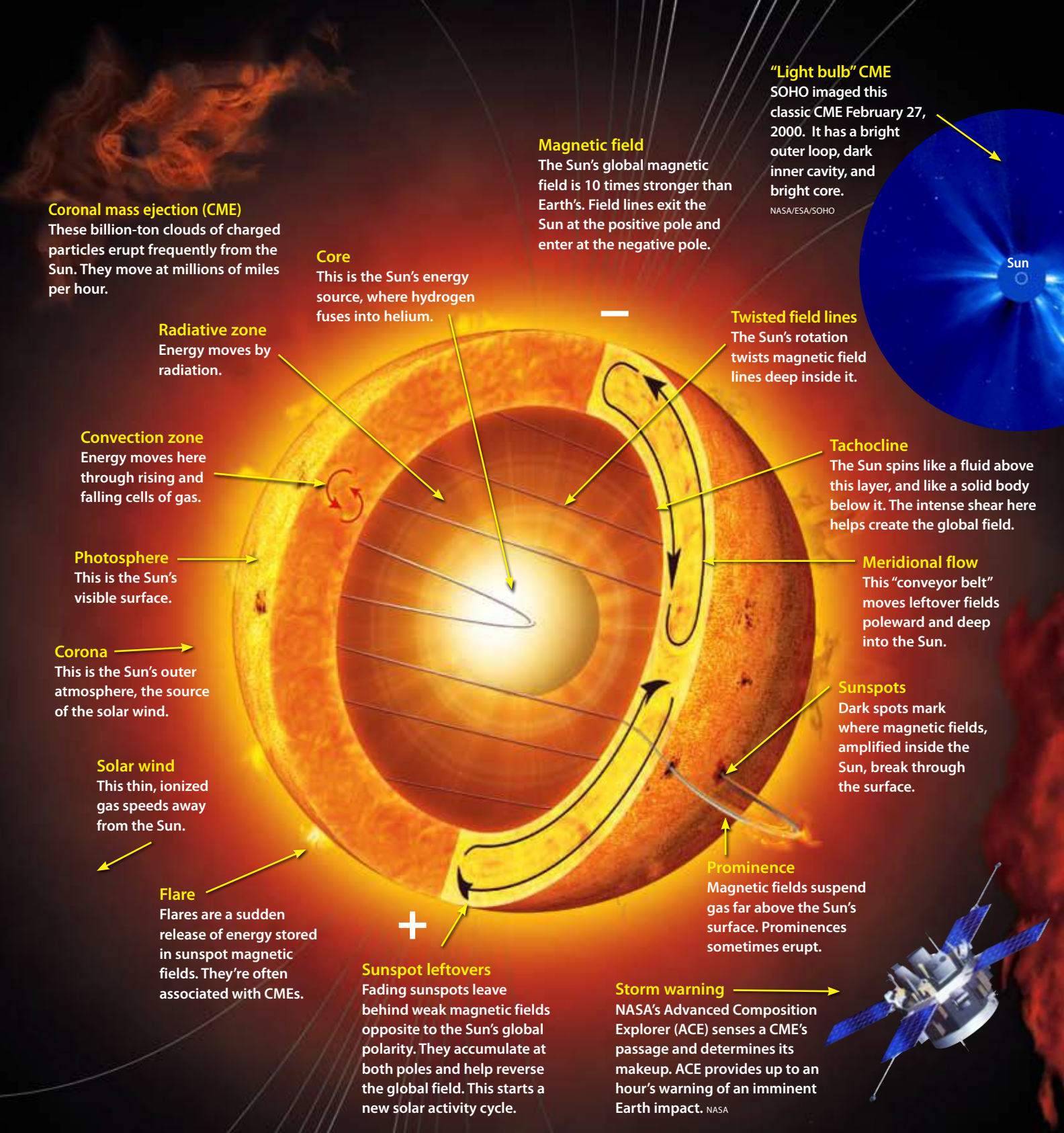
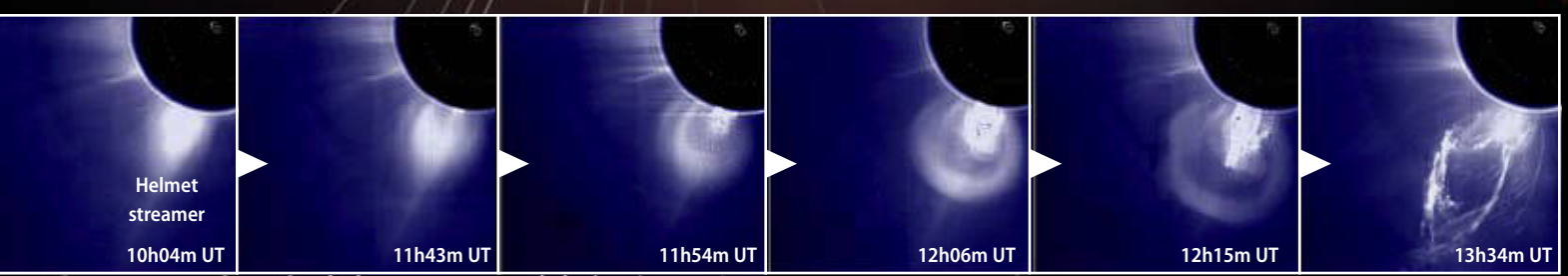
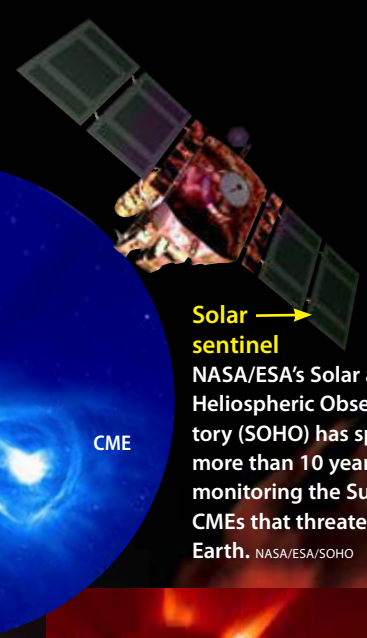

Coronal mass ejection (CME)
These billion-ton clouds of charged particles erupt frequently from the Sun. They move at millions of miles per hour.
Magnetic field
The Sun's global magnetic field is 10 times stronger than Earth's. Field lines exit the Sun at the positive pole and enter at the negative pole.
"Light bulb" CME
SOHO imaged this classic CME February 27, 2000. It has a bright outer loop, dark inner cavity, and bright core.
NASA/ESA/SOHO
Sun
Core
This is the Sun's energy source, where hydrogen fuses into helium.
Radiative zone
Energy moves by radiation.
Twisted field lines
The Sun's rotation twists magnetic field lines deep inside it.
Convection zone
Energy moves here through rising and falling cells of gas.
Tachocline
The Sun spins like a fluid above this layer, and like a solid body below it. The intense shear here helps create the global field.
Photosphere
This is the Sun's visible surface.
Meridional flow
This "conveyor belt" moves leftover fields poleward and deep into the Sun.
Corona
This is the Sun's outer atmosphere, the source of the solar wind.
Sunspots
Dark spots mark where magnetic fields, amplified inside the Sun, break through the surface.
Solar wind
This thin, ionized gas speeds away from the Sun.
Prominence
Magnetic fields suspend gas far above the Sun's surface. Prominences sometimes erupt.
Flare
Flares are a sudden release of energy stored in sunspot magnetic fields. They're often associated with CMEs.
Sunspot leftovers
Fading sunspots leave behind weak magnetic fields opposite to the Sun's global polarity. They accumulate at both poles and help reverse the global field. This starts a new solar activity cycle.
Storm warning
NASA's Advanced Composition Explorer (ACE) senses a CME's passage and determines its makeup. ACE provides up to an hour's warning of an imminent Earth impact. NASA



A CME is born. On August 18, 1980, NASA's Solar Maximum Mission satellite watched as a dense, bright portion of the Sun's corona — a feature called a helmet streamer — gradually inflated. After 3.5 hours, this streamer exploded outward as a CME. NASA/SMM/HAO

The Sun's biggest blasts

Coronal mass ejections, our star's largest eruptions, shoot billions of tons of plasma into space. /// TEXT BY FRANCIS REDDY; ILLUSTRATION BY ROEN KELLY



Solar sentinel
NASA/ESA's Solar and Heliospheric Observatory (SOHO) has spent more than 10 years monitoring the Sun for CMEs that threaten Earth. NASA/ESA/SOHO

Enormous outbursts
The Sun, shown as a white circle in this SOHO view, is 109 times Earth's size. NASA/ESA/SOHO

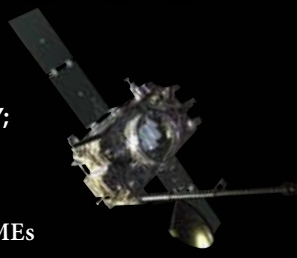
The Sun's pearly corona, visible briefly from Earth during total solar eclipses, appears placid. Beginning in the 1970s, though, space-borne solar telescopes began to reveal that the corona hosts the Sun's biggest eruptions — coronal mass ejections (CMEs).

A CME is a bubble of plasma — electrons, ions, and magnetic fields — shot from the Sun. A single CME can blast up to 10 billion tons of matter at speeds greater than 6 million mph (9.7 million km/h).

One CME erupts each week at the ebb of the Sun's 11-year activity cycle. During solar maximum, three or more CMEs can blast off in a single day.

No one knows what causes CMEs. They're often associated with solar flares and eruptive prominences, two other forms of solar outbursts. But CMEs also occur when these features aren't present.

When CMEs sweep past Earth, they can excite storms that make bright aurorae, the northern (and southern) lights. But such storms also can harm satellites and damage power-transmission equipment on the ground.



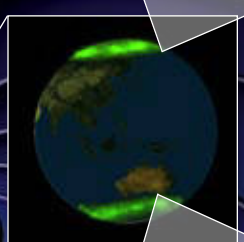
STEREO A
This probe flies ahead of Earth in its orbit to get a different angle on CMEs. NASA

A coronal mass ejection can reach Earth in as little as 15 hours.

Bow shock
A standing shock wave forms where Earth's magnetosphere first slows the solar wind.

Earth's magnetosphere
Ions trapped in Earth's magnetic field form this structure. When CMEs hit, the magnetosphere shudders and sends bursts of ions earthward.

Green curtain
Incoming particles excite atmospheric gases and create the otherworldly glow of the aurora, or northern (and southern) lights. JAMES A. ROSENSTOCK



Auroral ovals
Earth's magnetic field funnels charged particles into the polar regions. As a result, glowing rings of auroral activity cap Earth's poles. NASA/POLAR

Van Allen radiation belts

Magnetic field lines
Electrically charged particles spiral around Earth's magnetic field lines.

Neon in the sky
Green is the most common auroral color, but stunning yellows, reds, and violets occur as well. JAMES A. ROSENSTOCK

STEREO B
The twin Solar and Terrestrial Relations Observer (STEREO) probes will give scientists the first 3-D look at a CME. STEREO B orbits behind Earth in its orbit, while STEREO A flies ahead. NASA

Astronomy magazine

ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: the difference between the Big Bang and black holes, how spacecraft navigate the asteroid belt, and sky distances.

BIG BANG VS. BLACK HOLES

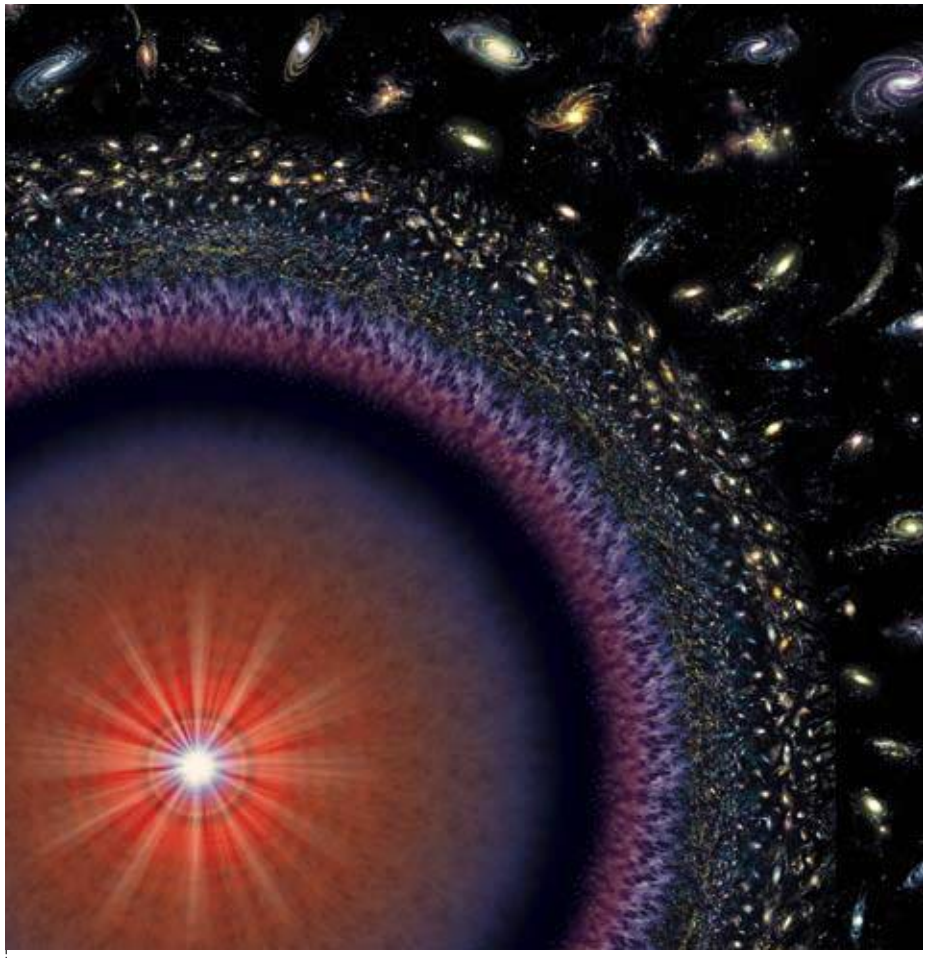
Q: If the universe began in an infinitely small volume, why isn't the universe a single supermassive black hole? — **PAUL HANNAN,** PIERREFONDS, QUEBEC, AND **COLTON BROOKS,** VIRGINIA BEACH, VIRGINIA

A: If you took all the matter we see today and compressed it to a single point, it would form a black hole. But **it's a popular misconception to imagine the Big Bang as an explosion of matter from a particular point in space-time.** In reality, space-time itself is expanding.

Today, we observe the universe spreading out and cooling down. Assuming this expansion has been going on for a long time, cosmologists imagine "rewinding" the universe to progressively earlier stages. As they trace the universe back to smaller sizes, it must get hotter and hotter — and, as it does so, the physics one needs to describe it changes. Today, the temperature of the universe, except for a few hospitable "hot spots" like galaxies, measures a few degrees above absolute zero, and the science is relatively well understood.

But 10 billion years ago, the universe glowed at many thousands of degrees — roughly the Sun's surface temperature. Then, how light interacts with ions — atoms stripped of their electrons — played a leading role everywhere in the cosmos.

Looking farther back, when the universe as a whole burned hotter than the Sun's core, interactions among atomic nuclei held paramount importance. The cosmos then was just a few cubic light-minutes in size — the smallest, earliest state for which scientists have any confidence in their ability to describe its properties. On Earth, only particle accelerators give us a glimpse of matter at energies before this time, when the universe was even hotter and nuclei gave way to quarks. This far back, we've reached the domain of conjecture and speculation.



REWINDING the expanding, cooling universe implies the cosmos was smaller, hotter, and denser in the past. Light emitted 380,000 years after the Big Bang forms the cosmic microwave background, which is as far back as astronomers can see. *ASTRONOMY:* ROEN KELLY

In the 1930s, cosmologists hotly debated what we'd see by rewinding cosmic expansion. One view, the so-called Milne universe, pictured matter receding to a single point in space-time. But cosmologists today know that space-time itself is expanding uniformly and in all directions, according to the Friedman-Robertson-Walker model of the universe.

Finally, scientists think quantum fluctuations broke the early universe's perfect uniformity. This ultimately allowed galaxies, stars, and planets to appear. Some researchers believe these inhomogeneities could have been large enough at early times to form tiny black holes. They're working to predict how we might detect such primordial black holes today. — **SIMON DEDEO,** UNIVERSITY OF CHICAGO

SAFE PASSAGE

Q: How do spacecraft safely navigate the asteroid belt?

— **JOHNATHON GREEN,** ANCHORAGE, ALASKA

A: Unlike Hollywood depictions, the asteroid belt, located midway between the orbits of Mars and Jupiter, is mostly empty space.

Imagine the asteroid belt as a disk-shape region with its inner edge at twice Earth's distance from the Sun (186 million miles). The outer edge reaches to 3 times Earth's solar distance (279 million miles), and the disk is about 9 million miles thick. The patch of space containing the asteroid belt has a huge volume — 1 trillion trillion cubic miles. That's a lot of space to fill.

There are hundreds of thousands of main-belt asteroids known, and many more await discovery. If, as some estimates suggest, a million objects lie in the asteroid belt, then **the average distance between asteroids is 730,000 miles (1.1 million km).**

So, the asteroid belt is hardly a dense debris field. It's easy for spacecraft to miss asteroids, given such large gaps between them. — **BILL COOKE,** NASA/MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALABAMA

IN THE KNOW

BLACK HOLE
An object whose gravitational pull inside a certain radius is so strong not even light can escape from it. Quantum fluctuations outside this radius may allow black holes to radiate small amounts of energy (Hawking radiation).

QUANTUM FLUCTUATIONS
Changes in the structure of space-time at the smallest scales.

SPACE-TIME
A four-dimensional space used to represent the universe — the three spatial dimensions we recognize (up-down, left-right, near-far) plus time.

ANGLES ON THE SKY

Q: What does it mean when you say things like "The Moon passes 4° south of Mars"?

— **KAPIL DHAIMADE,** MUMBAI, INDIA

A: Degrees (°) are the simplest way to measure angles. A full circle encompasses 360°, so 4° equals 1/90 of a circle. Scientists further divide angles into arcminutes (′), where 60′= 1°, and arcseconds (″), where 60″=1′. An arcsecond represents a tiny angle — it's the size a U.S. penny would appear at a distance of 2.4 miles (3.9 kilometers).

You can measure approximate angles in the sky using your hand. Make a closed fist and hold it at arm's length. Your fist will subtend an angle of about 8° — coincidentally, that's roughly the field of view seen through typical binoculars.

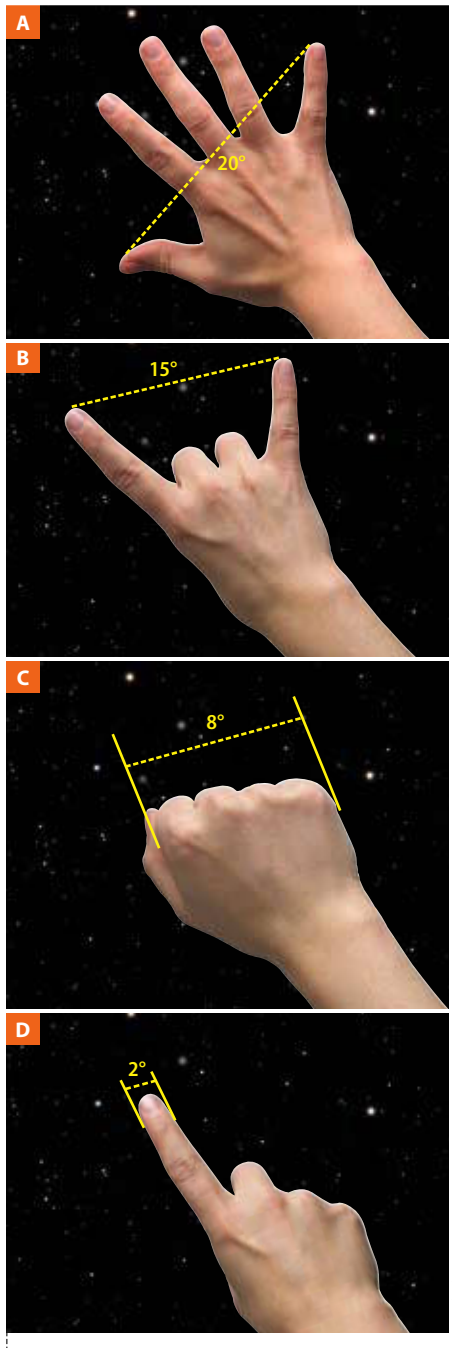
The width of a single finger held at arm's length forms an angle of about 2°. The easiest celestial body for measuring modest angles is the Moon, which spans an apparent diameter of 0.5° (30′).

Directions on the sky are a little harder to grasp. For those of us in the Northern Hemisphere, due north marks the direction to the North Celestial Pole (conveniently marked by the 2nd-magnitude star Polaris). If an object lies due north of another, it lies in the direction of Polaris.

The clearest situation arises when the two objects lie in the southern sky. In that case, the body that lies farther north appears directly above the other. **If the Moon passes 4° south of Mars, and they both lie in the south, then Mars appears 4° (8 Moon-widths) above the Moon.**

Things get more complicated if the objects lie in a different direction. Imagine the Moon passing Venus when they are low in evening twilight. In this case, you have to look west to see the objects, and the North Celestial Pole lies above and to their right.

So, if the Moon passes due north of Venus, our satellite doesn't appear directly above the planet. Instead, the Moon lies to Venus' upper right, with the exact angle depending on your latitude. — **RICHARD TALCOTT,** SENIOR EDITOR



ASTRONOMY: WILLIAM ZUBACK

YOUR HAND provides a convenient way to measure sky angles. An outstretched hand, held at arm's length, almost covers the Big Dipper's 20° span.

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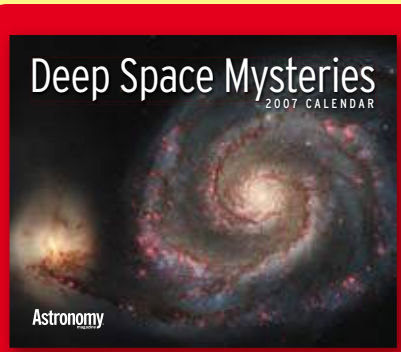

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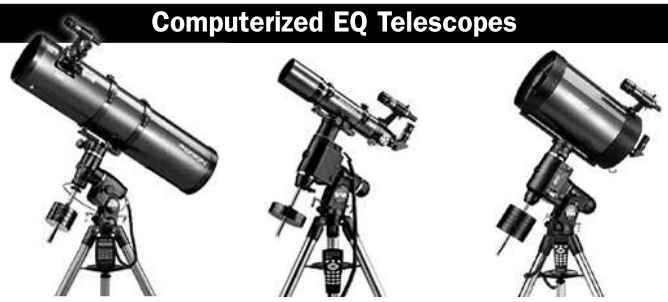

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IMAGINOVA.

The sky's most famous dark nebula intrigues amateur imagers and provides astronomers clues to the nature of interstellar space. /// **BY RAYMOND SHUBINSKI**

All about the Horsehead Nebula

At the end of the 19th century, one of the biggest topics in astronomy was black holes. These objects, however, were not then considered the gravitational maelstroms cosmologists think of today. Pre-20th century astronomers believed these starless voids were literal holes

in the sky. As telescopes improved, one of the most intriguing dark areas came to be known as the Horsehead Nebula, which lies in the constellation Orion.

As astronomy grew from an observational activity to one in which physics plays a major role, these dark regions slowly began to give up their secrets. To understand the role the Horsehead Nebula played, we need to understand the state of astronomy at the turn of the 20th century.

Dark mysteries

On a clear, dark, and moonless summer night, the Milky Way stretches from the southwest to the northeast. Toward the south, the rich star fields of the constellations Sagittarius the Archer and Scorpius the Scorpion are a playground for any observer with binoculars. Just above the spout of the teapot asterism in Sagittarius lies a number of glowing nebulae. Near the zenith, the summer triangle of Vega (Alpha [α] Lyrae), Deneb (Alpha Cygni), and Altair (Alpha Aquilae) frame a portion of the Milky Way. Deneb marks the tail of Cygnus the Swan, which seems to be flying along this river of light.

In *In Starland with a Three-Inch Telescope* (G. P. Putnam's Sons, 1909), American amateur astronomer William T. Olcott (1873–1936) urges Cygnus observers to look between the stars Alpha and Epsilon (ε). There, according to Olcott, you'll find a dark rift called the "coal sack," one of the so-called black holes. In the first edition of the book, Olcott offers no explanation for this intensely dark area.

Just 20 years later, in Olcott's 1929 revised edition of *Field Book of the Skies*, he

HORSEHEAD FACTS AND FIGURES

Names: Horsehead Nebula, Barnard 33 (B33)

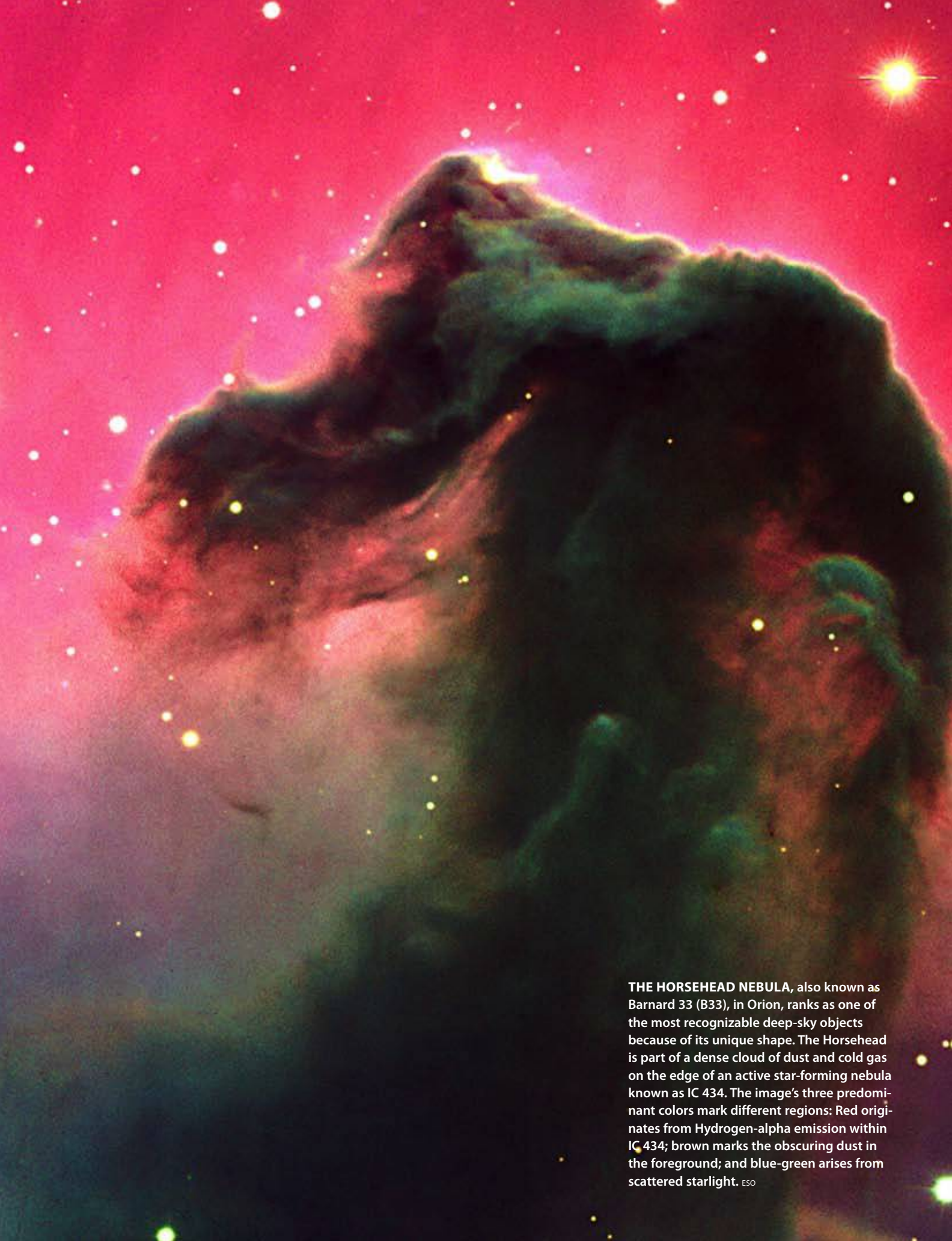
Type: Dark nebula

Position (2000.0):
Right ascension = 5h41m
Declination = –2°28'

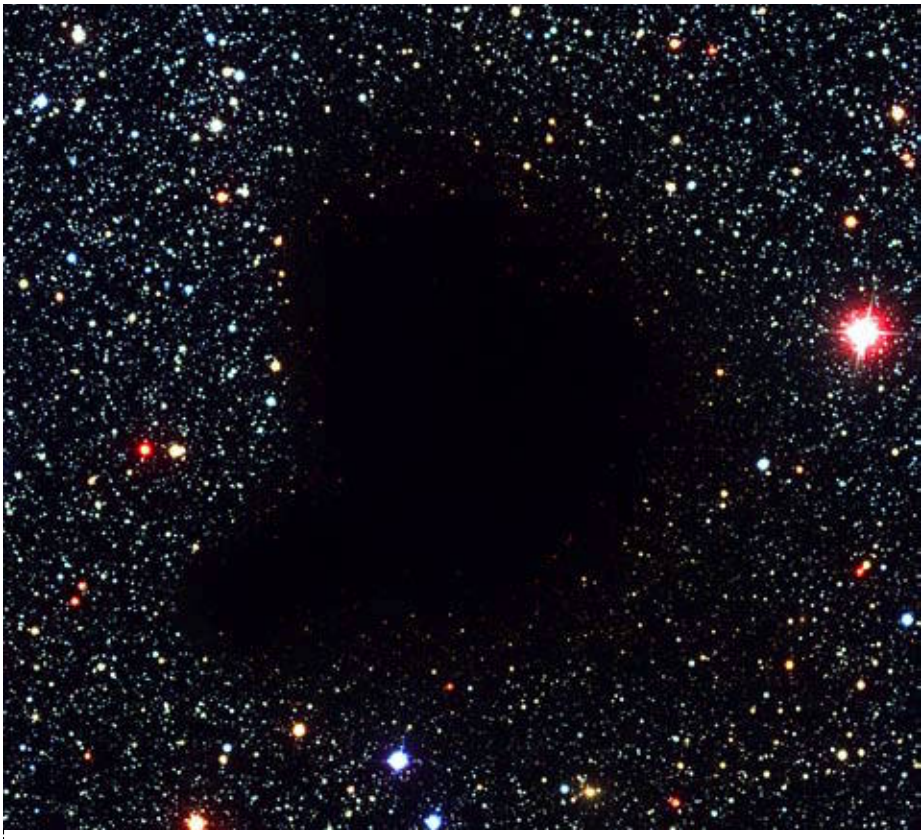
Size: 6' by 4'

Distance: 1,600 light-years

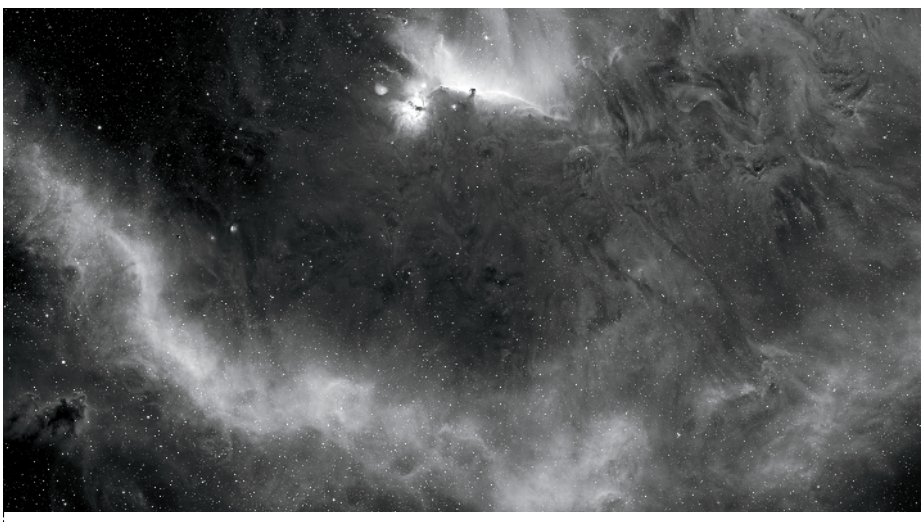
ONE OF THE EARLIEST photographs of the Horsehead Nebula was taken January 25, 1900, by English amateur astronomer Isaac Roberts through his 20-inch reflector. The Horsehead juts into the linear area beneath the brilliant star. Roberts published this photo in *The Astrophysical Journal*, Volume 17, 1903. LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, AND TECHNOLOGY



THE HORSEHEAD NEBULA, also known as Barnard 33 (B33), in Orion, ranks as one of the most recognizable deep-sky objects because of its unique shape. The Horsehead is part of a dense cloud of dust and cold gas on the edge of an active star-forming nebula known as IC 434. The image's three predominant colors mark different regions: Red originates from Hydrogen-alpha emission within IC 434; brown marks the obscuring dust in the foreground; and blue-green arises from scattered starlight. ESO



THE DARK CLOUD **Barnard 68 (B68), once considered a hole in space, marks a region of star formation. The opaque material eventually will contract, forming a star cluster. The field of view here measures 6.8' by 6.8'. B68 lies 500 light-years away in Ophiuchus.** ESO



THE ORION **Molecular Cloud contains the Horsehead Nebula, the Orion Nebula (M42), the Flame Nebula (NGC 2024), and many more. This image, made through a Hydrogen-alpha filter, reveals the Horsehead — the tiny, dark indentation in the bright area at top center — as a small part of a vast nebulous region in Orion.** PETER ERDMAN, EMBRY-RIDDLE UNIVERSITY

says: "These dark areas (the coal sacks) are now known to be clouds of cosmic matter that obstruct our view of the remote stars." How did astronomers come to this conclusion during two decades of observing? Part of the answer lies in one of the most famous constellations, Orion the Hunter.

Horsehead history

Orion ranks as the most outstanding winter constellation. And of all the nebulae in the sky, the glowing cloud in Orion's sword is the most famous. Designated M42 from Charles Messier's 18th-century catalog, it was first noted telescopically in 1610 by French astronomer Nicolas Peiresc (1580–1637) and later drawn by Dutch astronomer Christiaan Huygens (1629–1695) in 1659. The Orion Nebula is a powerhouse of star formation, but there's a lot more to this constellation than M42.

Orion's three "belt" stars prove useful in locating the Horsehead Nebula. Under a dark sky, an 8-inch or larger telescope will show a hint of glowing nebulosity near Zeta (ζ) Orionis, the easternmost star in the belt. Move your scope so Zeta lies just outside the field of view, and you should see more of the nebula. The brightest portion to the upper left of Zeta is NGC 2024. A distinct dark lane bisects this glowing cloud. A fainter cloud of glowing gas, IC 434, extends below Zeta. This hydrogen cloud passes to the left of 4th-magnitude Sigma (σ) Orionis. IC 434 measures 18 light-years long and is set aglow by Zeta's energy. Look carefully to see the Horsehead Nebula halfway down the length of IC 434.

The Horsehead rates as a difficult object to see visually. Many observers never have

RELATIVES OF THE HORSEHEAD

Not all objects similar to the Horsehead Nebula span light-years. For example, in nearly the opposite part of the sky from the Horsehead lies the molecular cloud Barnard 68 (see image to the left), a dense collection of dust and molecules that absorbs background starlight.

The cloud's dust grains — primarily made of carbon, oxygen, and silicon — mix with vast amounts of hydrogen and helium and a small amount of carbon monoxide. In the case of Barnard 68, the cloud measures only about 3 trillion miles across (about half a light-year). Compare that to the great Orion Molecular Cloud, which measures hundreds of light-years across.

These clouds, with their unbelievably frigid temperatures (on the order of 10 Kelvin), serve as stellar birth places. Such regions contain all the needed ingredients to form new stars. The Orion Nebula itself harbors a stellar nursery in an area familiar to observers: the Trapezium. Similar regions lie along our galaxy's plane. The same conditions exist in the Horsehead Nebula, and astronomers have detected young stars near the base of the "neck." — *R. S.*

HORSEHEAD NEBULA images normally show an object that protrudes from a large dark cloud into a region brightly lit by glowing hydrogen gas. The scene changes dramatically when examined by the European Space Agency's Infrared Space Observatory. Some light regions become dark, while the dark cloud glows with filaments shining by the infrared light emitted by interstellar dust. Only the top of the horse's head remains. ESA/ISO/ISOCAM AND L. NORDH (STOCKHOLM OBSERVATORY) ET AL.

glimpsed this dark cloud. But its observing history is every bit as intriguing as its physical nature. Edward Pickering (1846–1919), director of Harvard College Observatory, photographed IC 434 and detected a hint of the horsehead shape in 1888. Welsh-born amateur astronomer Isaac Roberts (1829–1904) captured the first really outstanding image of this dark object.

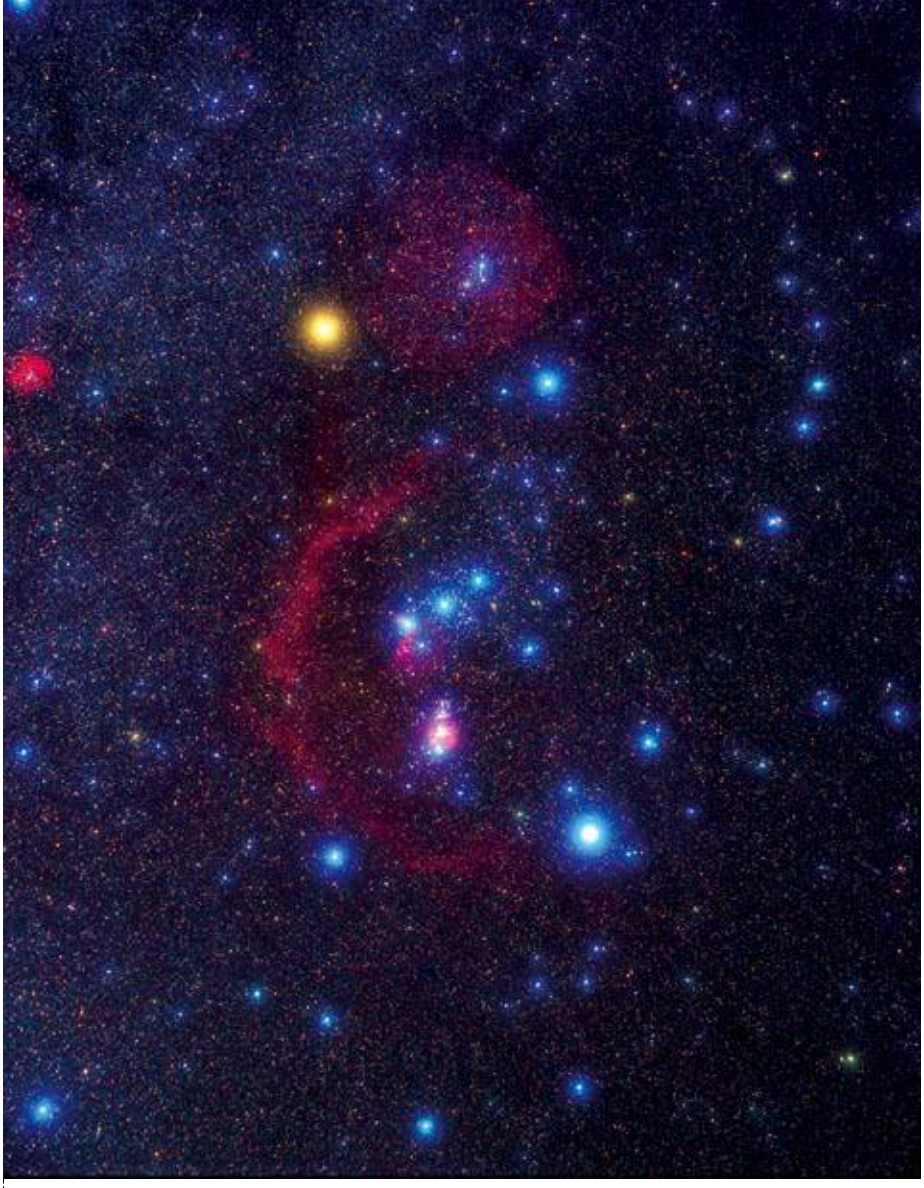
Roberts made a fortune in the construction industry in Liverpool, England. Like many educated Victorians, Roberts became interested in astronomy. Having achieved financial success, he became a "gentleman scientist," with no ties to any educational organization. Roberts loved photography and soon developed techniques for taking long-exposure images at the telescope. In the late 19th century, this was no easy task. Roberts began his work by using a portrait lens. As he refined his techniques, he produced amazing images of celestial objects.

Roberts also produced a set of photographs of English astronomer William Herschel's list of 52 nebulous objects, published by Herschel in 1811. Roberts published his results in *The Astrophysical Journal* (Volume 17, 1903). On page 77 sits Plate IV showing the nebula around Zeta Orionis. The now familiar shape of the Horsehead Nebula is clearly visible.

Raymond Shubinski *is the director of Science City/Attractions in Kansas City, Missouri.*

LARGE DARK FEATURES also exist within the Milky Way. About a dozen dark nebulae cataloged by American astronomer Edward Emerson Barnard combine to form the Great Dark Horse in Ophiuchus. You'll see the horse's form easily from a dark site. JOHN CHUMACK

THE REGION around the Horsehead Nebula looks different through the near-infrared eyes of the Two Micron All-Sky Survey (2MASS). The large, bright Flame Nebula (NGC 2024) sits to the left. Another, smaller bright nebula, NGC 2023, sits by itself. To its upper-right, you can glimpse the faint wisps of the Horsehead Nebula. 2MASS/E. KOPEN AND R. HURT (IPAC)



ORION is full of bright and dark nebulae. At the scale of this picture, you can't see the Horsehead Nebula. Close examination of the original image under high magnification, however, shows the Horsehead as a dark protrusion against a bright reddish background that lies just under the lowest star in Orion's belt. BILL AND SALLY FLETCHER

In the catalog listing in the same volume, Roberts describes the image in almost breathtaking words: "1900, Jan. 25 — Sky clear; stars very numerous on p. [preceding] half of plate, but few on f. [following] half, where there are large areas of stars; large cloud of nebulosity n. [north] f. zeta Orionis with broad division void of stars, but with some nebulosity in s. [south] f. to n. p. directions breaking up the clouds into separate masses. To the s. of zeta is a stream of nebulosity, 54 minutes of arc in length with an embayment free from nebulosity dividing it in half."

What was this embayment that resembled the head of a stallion? At least one writer speculated this and other such dark regions like the Coal Sack in the southern constellation Crux were windows or portals into heaven! Ten years later, a self-taught American astronomer named Edward Emerson Barnard (1857–1923) shed some light on this dark matter.

Working in the dark

In Volume 38 of *The Astrophysical Journal* (1913), Barnard published "Dark Regions in the Sky Suggesting an Obscuration of Light." Barnard had done work on the region around Zeta Orionis with the 36-inch Crossley refractor while at the Lick Observatory in California. By the time he published his 1913 paper, he was on the right track: "The so called 'black holes' in the Milky Way are of very great interest," he wrote. "Some of them are so definite that, possibly, they suggest not vacancies, but rather some kind of obscuring body lying in the Milky Way, or between us and it, which cuts out the light from the stars."

Barnard and other astronomers were beginning to grasp the complex three-dimensional nature of the region that includes the Horsehead Nebula. Barnard observed the Horsehead Nebula (now designated Barnard 33, from a list of 349 dark nebulae Barnard cataloged) visually with the 40-inch Yerkes Observatory refractor in Williams Bay, Wisconsin. He wrote, "The outlines of the spot — so sharp and clear in photographs of this region — could not be made out with any definiteness. The view showed that the spot is certainly not clear sky, for the field was dull, apparently indicating the presence of some material substance at this point. To me the observation would confirm the supposition of an obscuring medium."

Also, while working on a photographic survey of selected Milky Way regions, Barnard discovered a huge structure in Orion now called Barnard's Loop. This object appears to be the remains of a massive supernova that took place 3 million years ago. The Loop is part of a more complex structure that takes in most of Orion and extends eastward into Monoceros.

ONE TOUGH OBSERVATION

Once considered the "ultimate" observing test, the Horsehead Nebula isn't impossible to see if you heed these tips:
1) Use a big telescope. Observers have seen the Horsehead through 5-inch scopes, but not easily.
2) Observe from a dark site, and let your eyes dark-adapt for at least 15 minutes.
3) Increase the magnification, and slightly shift your scope to position the bright star Alnitak (Zeta [ζ] Orionis) outside the field of view.
4) Use the finder chart of Orion on page 71 to locate the Horsehead's general area. Then, a photograph will help you to pin down its exact location.
5) When you do approach the eyepiece, begin by searching for the bright nebula IC 434. If you can't see it steadily, you won't see the Horsehead.
6) One narrowband filter — Hydrogen-beta (Hβ) — makes observing the Horsehead easier. Such a filter enhances surprisingly few objects, but the list also includes the California Nebula (NGC 1499) in Perseus. — *Michael E. Bakich*

A quarter-century ago, astronomers studying the regions between stars thought molecules were rare because of the extreme cold of interstellar space. Research at the Harvard-Smithsonian Astrophysical Observatory with radio telescopes has shown just the opposite. In areas where temperatures hover just above absolute zero, hydrogen atoms combine into molecules and form vast molecular clouds.

The sheer size and mass of clouds such as the Horsehead allow molecules to "clump" together to begin star formation. But more than meets the eye is at work in these complex objects.

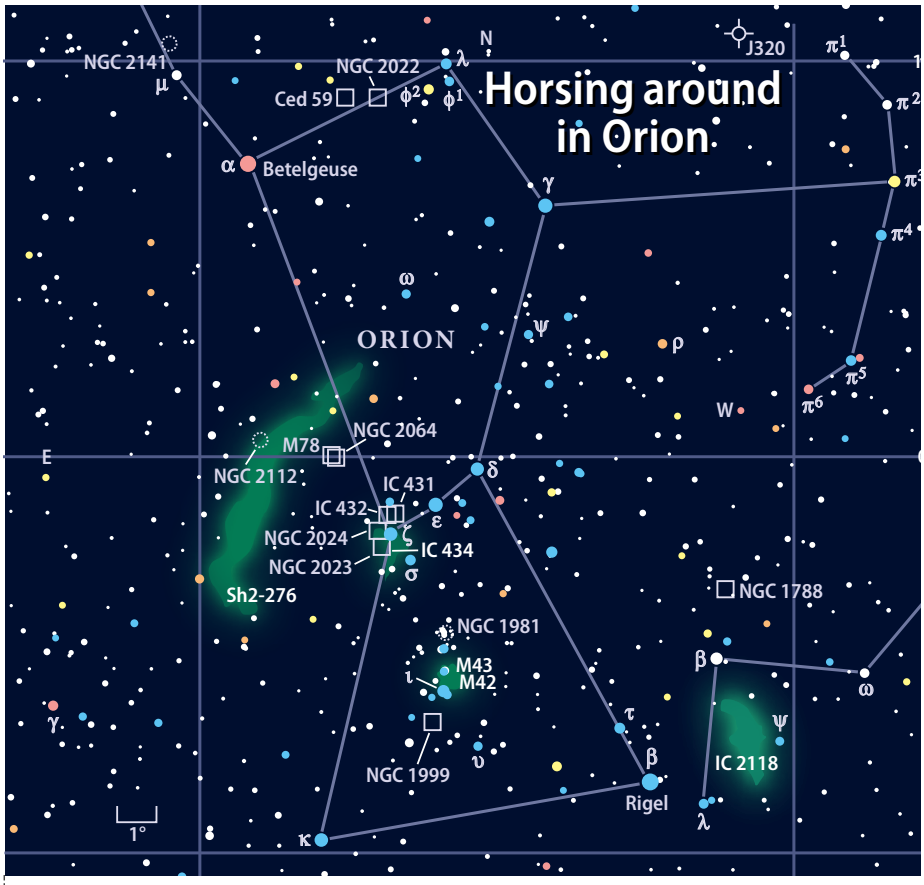
For many years, astronomers have been examining the role magnetic fields play in shaping these great clouds. In the case of the large cloud in Orion — called the Orion Molecular Cloud — numerous supernovae exploded millions of years ago, blasting shock waves and stellar material into the cloud. These explosions carried magnetic fields with them.

During most of the 20th century, the standard model for these fields indicated spherical structure. This didn't fit the observations well, and in January 2006, astronomers using the National Radio Astronomy Observatory's radio telescope at Green Bank, West Virginia, announced the "Slinky" model of magnetic-field structure.

Astronomers looked at long filaments of molecular clouds and found the magnetic field is wrapped around them in corkscrew fashion. This field's shape plays an important role in molecular-cloud origin and, ultimately, new-star formation.

Nineteenth- and early-20th-century astronomers such as Roberts and Barnard could only guess at the true nature of the Horsehead Nebula and the dark "black holes" they photographed. In the 21st century, we can tick off the facts about the Horsehead Nebula in a few sentences: The nebula — visible to the naked eye — lies about 1,600 light-years away and is composed of frigid clouds of light-absorbing molecules. The Horsehead Nebula marks just one site of star formation taking place in the vast Orion Molecular Cloud.

It has taken generations for astronomers to learn these facts, and they speak of almost incomprehensible processes — processes that, 4.5 billion years ago, brought our world into being. So try to glimpse this dark horse of the night, and know that you are witness to creation. A



USE THIS FINDER chart to locate the general area of the Horsehead Nebula, which lies 31' south of Zeta (ζ) Orionis. The Horsehead forms part of a dark cloud that sits on the edge of IC 434 with the horse's "head" protruding into IC 434. *ASTRONOMY:* ROEN KELLY AND RICHARD TALCOTT

LOOK CLOSELY to see the Horsehead Nebula in this region around Orion's belt — the three brilliant stars forming a diagonal line from the lower left to the upper right. Astronomers combined red- and blue-sensitive plates taken with the Samuel Oschin Telescope at Palomar Observatory between 1987 and 1991 to make this image. The Horsehead sits at lower left, a dark protrusion just below the lowest of the belt stars. DIGITIZED SKY SURVEY, ESA/ESO/NASA

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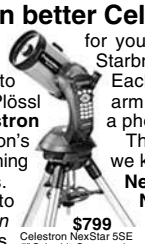
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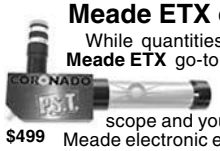

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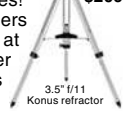

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A renowned astroimager shoots the Moon using an inexpensive webcam. /// **TEXT AND IMAGES BY ROBERT REEVES**

How to make a lunar mosaic

Webcams make it possible to achieve high-resolution images without breaking the bank.

Assembling overlapping, narrow-field webcam lunar images into high-resolution mosaics produces images reminiscent of those from 1960s' NASA lunar probes. All it takes to create seamless high-resolution lunar mosaics is an off-the-shelf webcam, an amateur telescope, free software, and some easy-to-acquire imaging skills.

Webcams have proven amazingly effective tools for lunar and planetary imaging. It seems counterintuitive that a simple, low-resolution video camera lighter than most eyepieces can out-resolve conventional 35mm film and digital cameras. But a number of factors make using a webcam the most effective way to acquire high-resolution images of solar system objects. A webcam is inexpensive, easy to operate, and delivers excellent results quickly. Best of all, the software for controlling the camera and processing your images is free.

THE ATIK ATK-2HS webcam-style astrocamera uses a small imaging sensor. Coupled with the long focal length of moderate-size telescopes, this sensor allows you to image the Moon in great detail.

The charge-coupled device (CCD) in a typical webcam measures 4.5 millimeters diagonally. Thus, the webcam's field of view through a telescope is small. The magic of webcam planetary imaging is the ability to extract amazing detail through image-stacking and image-processing software.

A webcam, even under mediocre seeing conditions, captures the Moon in greater detail than I see visually. Thus, a good lunar webcam image makes up in resolution what it lacks in field of view. During periods of excellent seeing, a webcam attached to a well-collimated 10- to 14-inch telescope can image the lunar surface with half-mile (1 kilometer) resolution. Such resolution rivals research imagery previously taken with professional equipment.

For many observers accustomed to the wider field of view available with conventional film and digital cameras, a webcam's keyhole-size view leaves something to be desired, even if the picture is highly detailed. But imagine a high-resolution, 4,000x4,000-pixel image of the lunar disk that shows greater detail than we can see through a telescope eyepiece. While expensive CCD cameras can take such images, their cost prices them out of most astroimagers' league.

The basics

To image the Moon, I use two cameras: a Philips SPC900NC webcam and an Atik

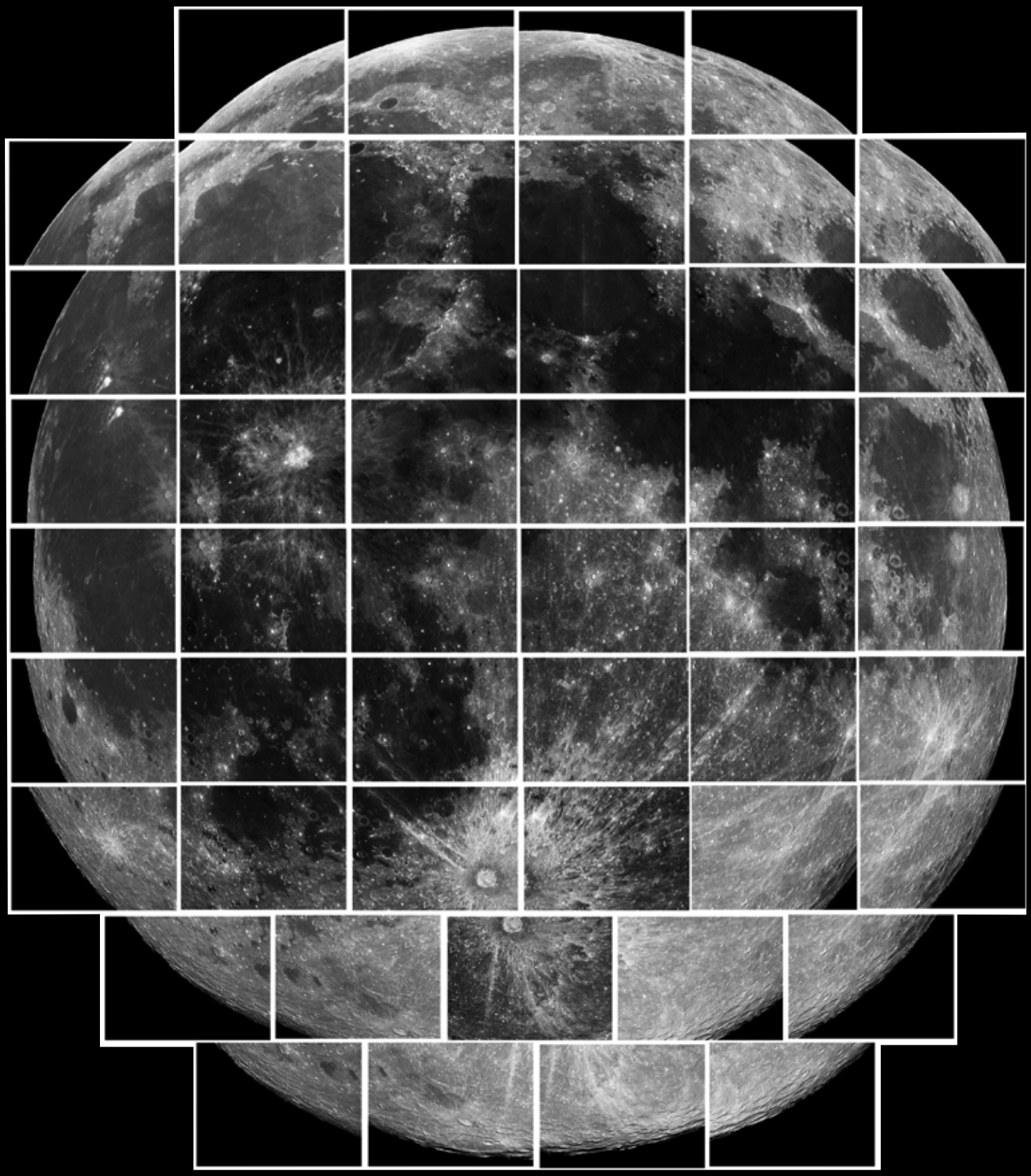
THE PHILIPS SPC900NC webcam's ¼-inch color CCD sensor has 5.6-micron pixels and requires a telescope adapter.

ATK-2hs, which is a commercially modified webcam equipped with a larger CCD sensor. However, you can use any webcam with a CCD sensor (many have less-sensitive CMOS sensors). The SPC900NC uses a Sony ¼-inch ICX098BQ color CCD sensor with 5.6-micron pixels.

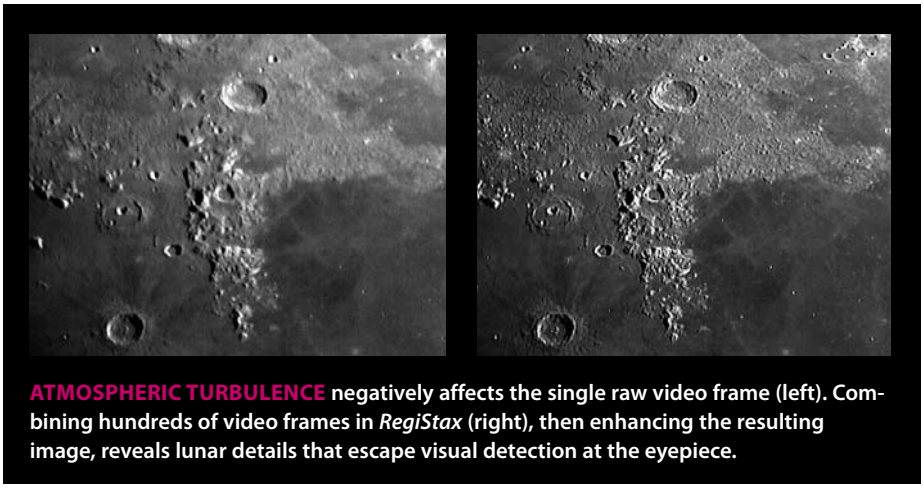
The Atik ATK-2hs uses a larger, ⅓-inch Sony ICX424AL black-and-white CCD sensor with 7.4-micron pixels. Both cameras have the same 640x480-pixel imaging array, but the larger monochrome pixels give the Atik camera more sensitivity, produce less electronic noise, and allow faster shutter speeds. Using a faster shutter speed reduces the effects of atmospheric turbulence, which can degrade any astroimage.

Atik cameras already are equipped with a 1¼" telescope adapter. To use the standard Philips webcam on a telescope, you must substitute an adapter for the camera's lens. You can adapt these lunar imaging techniques for use with many other webcams.

Whichever camera you use, be sure to install an infrared filter in the camera adapter. Webcams are sensitive to infrared wavelengths, and because most refracting telescopes can't bring infrared wavelengths to focus on the same plane as visible light, this infrared sensitivity will degrade your image. This is not a problem with reflecting telescopes, which focus



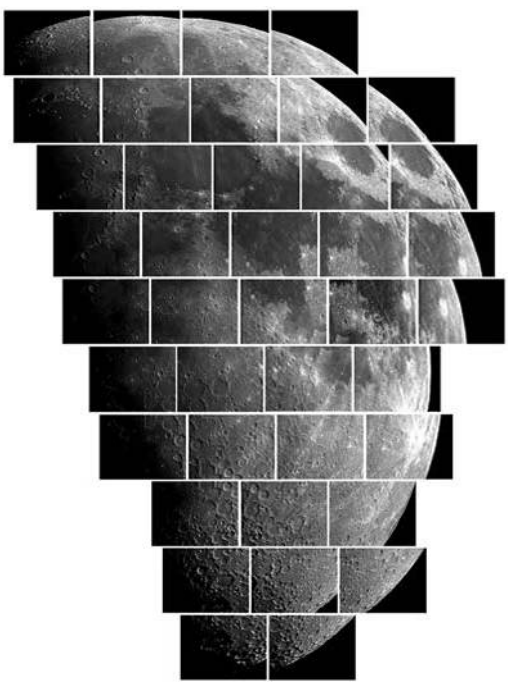
THE AUTHOR created this grid-like layout of 49 separate images. He used a Philips ToUcam 840 webcam and a Celestron 2,000mm focal length Schmidt-Cassegrain telescope. You need a large number of overlapping fields to image the Moon's entire face.



ATMOSPHERIC TURBULENCE negatively affects the single raw video frame (left). Combining hundreds of video frames in *RegiStax* (right), then enhancing the resulting image, reveals lunar details that escape visual detection at the eyepiece.

both visible and infrared wavelengths on the same plane; however, the filter will also protect the CCD sensor from dust, so it's a good idea no matter which type of scope you own.

You'll need a computer at the telescope to operate the webcam and record images. A laptop computer is especially convenient. Webcams produce a huge amount of video data, so be sure your hard drive has lots of available space — at least 20 gigabytes. A webcam can produce a 200-megabyte AVI-format file for each video sequence. With an 8-inch f/10 telescope on an equatorial mount, it may take as a many as 50 overlapping images to create a mosaic of the Full Moon.



FORTY INDIVIDUAL IMAGES comprise this First Quarter lunar mosaic. Images overlapped by about 25 percent.

Acquiring images

Before you image the Moon, you must orient and focus the camera. A webcam's small field of view makes both of these tasks challenging. First, aim the webcam at the Moon's northern limb and slew the telescope back and forth in right ascension. Orient the camera so the lunar limb passes parallel with the camera's left-right view. Properly orienting the camera simplifies moving from one mosaic field to the next while imaging.

Because a webcam's telescopic view is narrow, just touching the telescope's focus knob will introduce a vibration that causes the image to shake, making it difficult to achieve fine focus. Using an electric focuser significantly reduces such vibrations.

If you don't own one, here's my trick to reduce focusing shake: Clip a clothespin to the focuser. The additional leverage allows for focusing with a gentle finger-push instead of grasping the focuser. Another trick is to focus on a nearby star, then slew back to the Moon.

The camera-control software of choice for doing webcam astrophotography is *K3CCD Tools*, created by Peter Katreniak. *K3CCD Tools* provides an easy-to-use interface for setting the frame rate and the video recoding time, and it automates the file-naming process by sequentially assigning a new name to each video capture.

This last feature is convenient because the standard Philips webcam-control software overwrites the video file unless you supply a new file name. (The *K3CCD Tools* crosshair overlay helps frame mosaic segments.) *K3CCD Tools* also converts the standard MPG-format video coming from the SPC900NC webcam to AVI, the format expected by image-stacking software.

Shoot the Moon

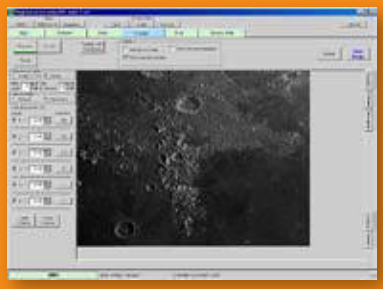
For lunar imaging, set the webcam's resolution to 640x480 pixels and disable video compression. At frame rates higher than 5 per second, webcams rely on video compression to pass large amounts of image data over the camera/computer USB connections. Compression creates artifacts that degrade images, so I don't use video-capture frame rates higher than this when imaging the Moon or planets. But, to produce lots of images for stacking, I set *K3CCDTools* to take a fixed 2-minute video at 5 frames per second, which captures 600 frames.

To maintain the same image density between segments spanning the Moon's entire face, you must manually adjust the webcam to one shutter speed and one gain setting throughout the entire sequence. While it is tempting to adjust the camera to fully expose the dim areas along the terminator, this grossly overexposes the fully illuminated lunar limb and results in an unpleasing final image. I've achieved my best results by setting the exposure to record the brightest areas of the lunar limb properly and let the dark terminator fade out naturally.

The Philips SPC900NC is sensitive to low light levels (as low as 1 lux), so shutter speeds are fast compared to film astrophotography. Shutter speeds of 1/50–1/250 second are typical; however, this depends on the Moon's phase and whether you use a magnifying Barlow lens with the webcam.

The webcam's gain setting is analogous to the film speed of a single-lens-reflex camera. The higher this gain setting, the more sensitive the camera becomes. But, just as using a higher film speed results in larger film grain, higher webcam gain amplifies the camera's electronic noise and creates bright speckles in the image. More gain equals more grain. Achieving balance between shutter speed and gain sensitivity results in a normal-contrast image. You'll get the best images with gain settings between 25 and 50 percent and adjusting the shutter speed while watching the live image. Leave the webcam's gamma and brightness levels alone so you don't end up clipping highlights.

Robert Reeves *is an astrophotographer and author who lives in San Antonio. His latest book,* Introduction to Webcam Astrophotography, *is published by Willmann-Bell (2006).*



***REGISTAX* FREEWARE is the key to high-resolution lunar and planetary webcam imaging. Select a bright lunar feature to use as an alignment reference, and the *RegiStax* program stacks the best video frames into a single low-noise image that is enhanced (lower of two above images) using wavelet image-processing filters.**

FORTY-NINE IMAGES went into making this Full Moon mosaic. The author took the images through a Celestron 8-inch f/10 Schmidt-Cassegrain scope and a Phillips SPC900NC webcam.

Capturing the mosaic segments used to assemble a wide-field lunar image requires careful telescopic navigation across the Moon's disk. After aligning and focusing the camera, I start at the Moon's northern limb and work left to right, acquiring sequential overlapping segments. It helps to know the Moon's topography, and a lunar map helps you identify surface features.

Allow about a 25-percent overlap for each successive segment. It may take up to 6 images to cover one swath across the Moon, depending on your telescope and the Moon's phase. Continue to the next swath by moving the field south and allowing a 25-percent vertical overlap with the first swath. A telescope with electric slow-motion control simplifies this process.

Lunar jigsaw puzzle

Stacking images during digital processing reduces noise, so the more video frames you stack together, the better — right? Stacking four images reduces noise by half, stacking nine images reduces noise by a factor of three, stacking 100 images reduces noise by a factor of 10, and stacking 1,000 frames reduces noise by a factor of 32. Continuing the process into thousands of video frames approaches the point of diminishing returns.

Regardless of how you assemble the mosaic, the conversion of an AVI file into a single image should begin with *RegiStax*, a program created by Cor Berrevoets. This automated image-stacking program allows you to select a minimum acceptable image-quality level for the stacked video frames. *RegiStax* then discards frames below this threshold. The latest version (3.0) remembers image-stacking parameters and other settings so you can automatically apply them to the next video you process. This lets you process subsequent mosaic sequences with as few as three mouse clicks per video.

Slight telescope-tracking errors and unsteady seeing slightly shift the imaging target during video capture. This creates a narrow gray or white border around the edge of the final still. *iMerge* mosaic-making software by Jon Grove excels at eliminating small borders. But you may need to crop out any large borders. I recommend *IrfanView*, created by Irfan Skiljan, for this task. *IrfanView* is both an image-viewing program and a basic image-processing program that can crop, rotate, resize, sharpen, and adjust color, brightness, and contrast.

I use *iMerge* to assemble individual segments into a finished mosaic. This small program produces big results. Simply drag and drop segments into place, then save the completed mosaic as a single image. You can align images with pixel-to-pixel accuracy by zooming in on the segments. *iMerge* blends the border between segments to create a seamless image.

After acquiring the essentials — webcam, telescope adapter, infrared filter, computer, and telescope — the cost to create your own NASA-like high-resolution lunar mosaics is nothing but time. All of the software I use for webcam-control, image-processing, and mosaic-making is free.

Successful imaging produces rewarding results: lunar mosaics you'll want to frame and hang on your wall.

ONLINE EXTRA Get more lunar-mosaic tips at www.astronomy.com/toc.

An historic vote pushes Pluto aside, but some scientists are crying foul. /// **BY FRANCIS REDDY**

Pluto gets the boot!

For Pluto fans, August 24 was Black

Thursday. That's when 424 astronomers in Prague, Czech Republic, sent Pluto — known since its 1930 discovery as the ninth planet — packing to the solar system's minor leagues. ❮ The historic decision marked the end of the International Astronomical Union's (IAU) 2-year attempt to formulate a scientific definition of "planet." The vote followed 8 days of sometimes contentious debate that began with the possibility of promoting three worlds. Instead, it ended with Pluto being demoted and charges that a minority of astronomers had upended the process.

Long, strange trip

It was Caltech astronomer Michael Brown's January 2005 discovery of 2003 UB_{313} — better known by its TV-inspired nickname, Xena, and now officially named Eris — that created the urgent need for a definition. Eris is 5-percent bigger than Pluto. So, if Pluto is a planet, wouldn't Eris be one, too?

As astronomy's official naming body, the IAU held off naming Eris and other large objects orbiting the Sun beyond Neptune until their planetary status could be determined. A committee of 19 astronomers was already attempting to come up with a science-based definition, but it deadlocked in October 2005.

In June and July 2006, a new seven-member panel, chaired by Harvard astronomer and historian Owen Gingerich, convened in Paris. The group unanimously agreed that gravity plays a determining factor. A planet, the panel stated, is any object orbiting a star that is neither a star itself nor the moon of another planet, and contains enough matter for gravity to force it into a nearly round shape. The group further agreed that Pluto should be recognized as the prototype for a new class of trans-neptunian objects to be called "plutons." The panel presented these ideas at the IAU meeting in Prague August 16.

Pluto meets the requirements. But so do three other objects: Eris; Ceres, the largest asteroid; and Charon, Pluto's largest moon. At just over half Pluto's size, Charon is so big that the pair's center of mass lies outside Pluto — the only such case in the solar system. If the IAU approved, all three objects would become planets.

Some disagreed with the panel's recommendation. Brown noted that more than 53 objects in the Kuiper Belt beyond Neptune potentially are big enough to qualify as planets under the proposed definition. Promoting Charon, known since its 1978 discovery as a moon, "didn't pass the smell test," he said.

And no one liked "pluton." Geologists quickly objected to appropriation of a well-established term in their field (it refers to a rocky nugget that cooled beneath a planet's surface). "What happens when we find a pluton on a pluton?" objected Allen Glazner, a geology professor at the University of North Carolina.

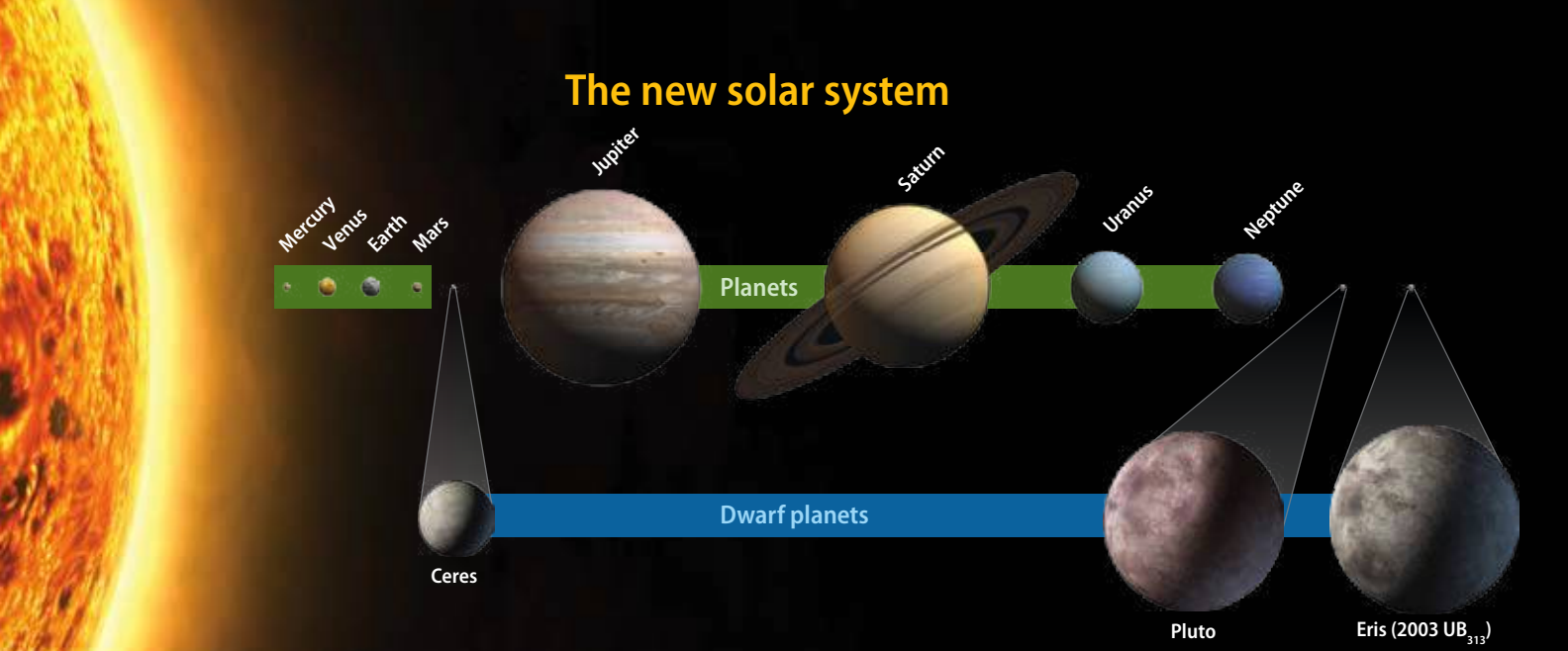
Nevertheless, the world's largest group of planetary scientists announced support

HUNDREDS of astronomers in Prague raise yellow voting cards to approve the IAU's planet definition August 24. MARTIN GEORGE

WHAT *IS* PLUTO?

Pluto is one of three recognized dwarf planets, with Eris (formerly 2003 UB_{313}) and Ceres. Pluto is also the prototype of an unnamed class of trans-neptunian objects that includes Eris. — *F. R.*

Francis Reddy *is an associate editor of* Astronomy.



THE SOLAR SYSTEM now contains eight planets, three dwarf planets, and a new class of objects beyond Neptune not yet named. The rest — including all moons and comets, and all asteroids except Ceres — are officially "small solar system bodies." IAU/MARTIN KORNMESSER/*ASTRONOMY*: ROEN KELLY

for the proposal the following day. The American Astronomical Society's 1,300-member Division for Planetary Sciences urged IAU members to approve the resolution. And that, it would seem, was that.

Astronomers revolt

But in a test vote held during a fractious Friday meeting, planetary scientists in Prague rejected the proposal 3 to 1. Of several alternatives suggested, one, offered by Julio Fernández of the University of the Republic in Montevideo, Uruguay, had broad appeal. It added the condition that a planet must also be "by far the largest object in its local population." The alternative passed a test vote 3 to 1.

Alan Boss of the Carnegie Institution of Washington and Paul Weissman of the Jet Propulsion Laboratory are among astronomers who agree that a planet's dominance of its environment is a key aspect of planethood. But including this criterion doomed Pluto. Neptune controls Pluto and about 100 other icy objects (called plutinos) by making them orbit twice for every three times Neptune orbits the Sun.

On August 22, two days before the vote, the planet-definition committee presented a tweaked version of its original resolution. Members loudly complained that the new version lacked any reference to a planet's orbital environment. The IAU hammered out a compromise measure in closed-door sessions the same afternoon.

On voting day, Jocelyn Bell Burnell, an expert on neutron stars at England's University of Oxford, moderated the proceedings with the help of playful visual aids. A blue balloon stood in for Neptune, while a plush toy of Disney's cartoon dog Pluto played the ninth rock from the Sun.

The final proposal consisted of four separate resolutions, and each was put to a vote. The first defined a planet as a round object that orbits the Sun and has cleared its orbital zone of debris. It introduced a new class of objects, called dwarf planets, which are round but have not cleared their orbital zones. It passed easily.

For Pluto, the critical vote was one that would put dwarf planets on par with the eight classical ones; it failed by a wide margin. In another vote, astronomers formally made Pluto a dwarf planet and recognized it as the prototype of a new class of objects orbiting the Sun beyond Neptune. A resolution that would name this class "plutonian objects" failed.

"I was relieved," says Brown. "Scientifically, there is no question this is the right way to go. Eight is enough."

Richard Conn Henry of Baltimore's Johns Hopkins University says, "I am delighted that rationality has prevailed."

Not everyone is so pleased. Gingerich says the compromise proposal replaced his committee's "carefully thought-out and unanimous recommendation" with a "flawed definition."

Mark Sykes, director of the Planetary Science Institute in Tucson, Arizona, agrees. Noting that only members actually present in Prague — about 5 percent of the total — could vote, he says, "There will be a lot of people who just choose to ignore it."

"It's ridiculous," declares Alan Stern, lead researcher for NASA's New Horizons mission to Pluto. He finds the clear-orbital-zone criterion far too ambiguous. "The IAU has embarrassed itself," he says.

"There are some common-sense issues with this," says Sykes. A Neptune-mass world found far in the Kuiper Belt now would rank as a dwarf planet. Sykes and Stern circulated a petition objecting to the decision, and 300 scientists signed on.

Brown, as the discoverer of what could have been the tenth planet, had more to lose than most. But he thought the decision would have been much the same had all the world's astronomers taken part. "I think it's time to close this debate and get on with the business of doing science," he says.

He added that all of the "what ifs" are where science gets fun. Yes, a Neptune-mass object far in the Kuiper Belt now wouldn't count as a full-fledged planet. "And wouldn't that be cool? It would wreck our semantics because it would also wreck our understanding of the solar system," he says. "It doesn't get any better than that." A

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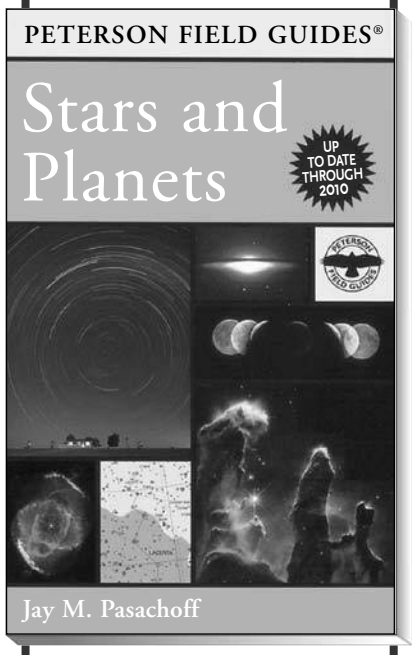

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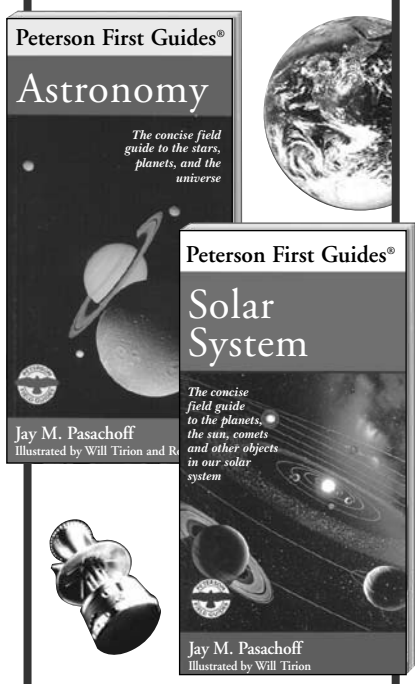
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18 must-read books for cloudy nights

Explore the Moon and Mars, investigate gravity, introduce yourself to the stars, and hold the universe in your hands. /// **BY LIZ KRUESI**

When the weather isn't cooperating and you can't observe the sky's wonders — or when you just want to learn more about what's out there — a good astronomy book is the closest thing to a clear sky. This past year has seen many great reads from all areas of astronomy, and here's a selection of the best.

Fascinated by everything?

The all-encompassing coffee-table volume ***Universe*** (DK Publishing, 2005) is edited by astronomer Sir Martin Rees. The first 330 pages cover topics ranging from relativity to ancient astronomy. The remaining pages discuss the constellations and include Northern and Southern hemisphere sky charts.

The encyclopedic ***What's Out There: Images from Here to the Edge of the Universe*** (Duncan Baird Publishers, 2005) boasts a stock of images from nearly 50 sources — including the Hubble and Spitzer space telescopes — to illustrate astronomical concepts. The authors follow an A-to-Z format and cover widely accessible topics, such as the planets, different galaxy types, and planetary nebulae. While this book doesn't define string theory or address other theoretical topics, it presents a substantial image collection that introduces many readers to observational astronomy.

For a comprehensive overview of today's physics, check out ***The New Physics for the Twenty-First Century*** (Cambridge University Press, 2006). Edited by Gordon Fraser, this textbook features chapters written by 23 prominent scientists in various areas of modern physics. The book targets undergraduate students and includes some calculus. However, most equations are boxed off, and readers who lack a math background can skip the equations and still comprehend the science. After an opening chapter on cosmology, the book then covers a wide range of topics, including chaos theory, quantum mechanics, and, biophysics.

Closer to home

Sail through our solar neighborhood through the eyes of space artists Ron Miller and William K. Hartmann in ***The Grand Tour: A Traveler's Guide to the Solar System*** (Workman, 2005). A complete revision of their popular 1981 book, this edition includes information about new space missions and telescopic discoveries of moons, minor planets, and comets. Follow the authors' tour with spacecraft images and 160 new show-stealing photorealistic art pieces.

Charles Frankel's ***Worlds on Fire*** (Cambridge University Press, 2005) offers another planetary-science tour, but this one has a specific theme — volcanism in the solar system. Frankel opens with the science of terrestrial volcanoes before touring Earth's volcanoes. This section includes not only basic facts, but also the tour's "itinerary" (what to expect when you visit each site). Frankel follows this format for each location — Earth, the Moon, Mars, Venus, and Jupiter's moon Io. Each section includes an overview of each body's volcanism, followed by a detailed tour of the volcanoes.

Simple Stargazing (HarperCollins, 2006) by Anton Vamplew is an introduction to observational astronomy. The first part describes how to find your way around the sky and what certain objects are (like variable stars, binary stars, and nebulae) — all useful information for beginners. Vamplew follows this with images and descriptions of each of the 88 constellations so readers can get acquainted with the night sky. There are also tips on how to observe the Moon, meteor showers, and eclipses.

Travel back in time

The story of gravity is a long, complex one, and author David

KIDS, ADULTS, amateurs, and professionals will find great books among these selections. *ASTRONOMY:* JIM FORBES

Liz Kruesi *is an assistant editor of* Astronomy. *Having grown up in Illinois near Lake Michigan, she doesn't let cloudy nights interfere with her enjoyment of astronomy.*

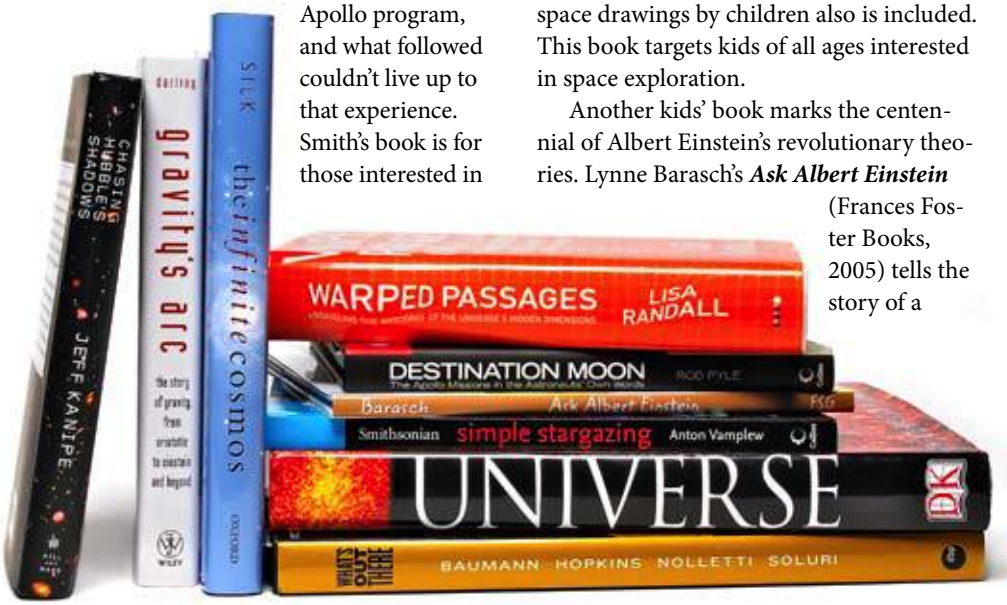
Darling's ***Gravity's Arc*** (John Wiley & Sons, 2006) tells it clearly. From Aristotle's early studies around 300 B.C. to the movements of planets, ballistics, and eventually, the warping of space-time, Darling covers a nearly 2,500-year history of humans' quest to comprehend this fundamental force. As you read Darling's book, you'll confirm a nagging suspicion: The more scientists discover, such as dark energy and the curved geometry of space-time, the more they don't understand.

In ***Halley's Quest*** (Joseph Henry Press, 2005), Julie Wakefield introduces readers to an Edmond Halley most of us don't know. While we think of the comet that bears his name, Halley made great advances in navigation — rooted in the difference between true north and magnetic north. Wakefield's retelling of Halley's three voyages to navigate the seas more carefully will make you appreciate the quest for science.

In the neighborhood

Rod Pyle's ***Destination Moon*** (HarperCollins, 2005) recounts the Apollo missions through narrative, transcripts, and retrospective commentary from the astronauts and mission scientists. Pyle covers all 17 missions using both celebrated and rarely seen photographs. For anyone interested in NASA's lunar exploration, Pyle's book flies you to the Moon.

Twelve men walked on the Moon during the Apollo program. Andrew Smith tracked down the nine men still living to answer, "What do you do after you've landed on the lunar surface?" for his book ***Moondust: In Search of the Men Who Fell to Earth*** (Fourth Estate, 2005). Many of these men reached their professional peaks during the Apollo program, and what followed couldn't live up to that experience. Smith's book is for those interested in the human side of the Apollo program. And, if you're not interested, chances are you will be by the time you finish reading this book. While politics and technology were obvious drivers of the Space Race, those personally involved gave it life.



Filled with over 200 beautiful images of the Red Planet, Olivier de Goursac's ***Visions of Mars*** (Harry N. Abrams, 2005) complements anyone's bookshelf or coffee table. De Goursac creatively named the chapters after the four philosophical elements: Earth, for martian geography and landscapes; Fire, for the martian volcanic history; Water, for the polar caps and the Red Planet's water history; and Air, for the martian atmosphere. Following these four chapters, De Goursac includes the fifth element of Man to discuss future human exploration and colonization.

In ***Roving Mars*** (Hyperion Books, 2005), Steve Squyres gives a firsthand account of exploring another world. Squyres is the principal investigator for the Mars Exploration Rovers mission, whose "explorers" have surveyed the Red Planet since January 2004. He weaves into his story his initial interest in Mars in 1977 during his undergraduate years, to where the mission was in 2005. You can read about Squyres' personal and professional involvement in the project.

Space fans of all ages

Do you have a question about space travel? Chances are it's answered in Lonnie Jones Schorer's ***Kids to Space: A Space Traveler's Guide*** (Apogee Books, 2006). With hundreds of questions from American school kids answered by scientists and technicians, this book covers everything from radiation to how gravity changes to what to pack for space travel. A CD-ROM with over 1,000 space drawings by children also is included. This book targets kids of all ages interested in space exploration.

Another kids' book marks the centennial of Albert Einstein's revolutionary theories. Lynne Barasch's ***Ask Albert Einstein*** (Frances Foster Books, 2005) tells the story of a young girl who just can't grasp math, and her sister who writes to Einstein for help. Aimed at 5- to 8-year-olds, this book is inspired by a true story and shows a rarely seen side of Einstein.

Pieces of Another World (Sylvan Dell Publishing, 2005) by Mara Rockliff, illustrated by Salima Alikhan, is a story of Jody and her father during her first meteor shower. This book's target audience is ages 3 to 8. Rockliff includes definitions, tips for enjoying a meteor shower, and even a recipe for "comet cookies."

The big ideas

Jeff Kanipe's ***Chasing Hubble's Shadows*** (Hill and Wang, 2006) focuses on the Hubble Space Telescope and Edwin Hubble's specialty, deep-space astronomy. Kanipe provides a clear, thorough overview of cosmology and deep-space astronomy and how the Hubble Telescope (namely, the Hubble Ultra Deep Field images) has contributed to the science. Kanipe spends a chapter on an area of cosmology that, until recently, didn't solicit much research — reionization and the formation of the first structures. Kanipe ends with where the science and telescope are headed.

For an explanation of string theory, extra dimensions, and other questions in cosmology, physicist Lisa Randall's ***Warped Passages*** (HarperCollins, 2005) is a good resource. Randall is a leading cosmology theorist even deemed by some as "the next Einstein" because of her unique way of looking at the world. And she can explain these concepts. To add character, each chapter starts with a song lyric, ranging from Frank Sinatra to Metallica. Randall concludes with a thorough glossary, which includes terms such as *de Sitter space* and *uncertainty principle*.

Astronomy professor Joseph Silk's ***Infinite Cosmos*** (Oxford University Press, 2006) focuses on where cosmology is today. Silk weaves in poets and philosophers' ideas and backs up those quotes with modern science. He spends the last fifth of the book laying out some intriguing theories — the universe might be infinite, multiverses could exist, time travel may be feasible, and intelligent life may prosper elsewhere in space — and ways for scientists to test them.

Whether you want to visit the Moon, the Red Planet, the past, or other dimensions, check out some of these books for many long nights of reading.

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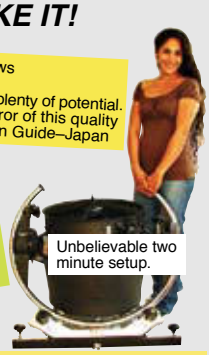

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Astronomy

SPECIAL RETROSPECTIVE

Top 10 astronomy stories
This past year, cosmologists peered into the Big Bang, astronomers tallied 200 alien worlds, and planetary scientists captured a comet.

Anatomy of a supersize star
Changes in Mira's complex atmosphere power this star's pulsations.

The sizes of sky objects
In this special illustration, the Moon's apparent size provides a yardstick for comparing the sky's best-known targets.

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DOUGLAS SPRIGG

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Besides observing, the event will include numerous lectures by astronomers, including Fred Watson of the Anglo-Australian Observatory and Paul Curnow of the Adelaide Planetarium.

For more information, visit www.arkaroola.com.au/events.php.

NOVEMBER 20–DECEMBER 1

Conference: Canary Islands Winter School of Astrophysics

Cabildo Insular de Tenerife Conference Center, Puerto de la Cruz, Canary Islands, Spain. The theme for this year's event is "The Emission Line Universe." For more information, visit www.iac.es/winters.

THROUGH DECEMBER 17

Planetarium show: 'Tis the Season

Newark Museum, Newark, New Jersey. This planetarium show profiles the winter sky's constellations and traces the development of holiday customs, from the Hanukkah menorah to Christmas tree lights. For more information, visit www.newarkmuseum.org/planetarium.

DECEMBER 1

Far Out Friday

Adler Planetarium and Astronomy Museum, Chicago. On the first Friday of every month, the Adler hosts an evening of astronomy-related fun, including observing, lectures, planetarium shows, and facility tours. For more information, call 312.922.7827; web site, www.adlerplanetarium.org.

DECEMBER 11–15

American Geophysical Union Fall Meeting in California

Moscone Center, San Francisco. This conference will provide an occasion for researchers, teachers, students, and consultants to discuss Earth and planetary science issues. *Astronomy* Editor David J. Eicher will attend. For more information, visit www.agu.org.

DECEMBER 11

Lecture: The Science of Spirit and Opportunity

Morrison Planetarium, California Academy of Sciences, San Francisco. Albert Haldemann of NASA's Jet Propulsion Laboratory will discuss the scientific results obtained by the Mars Exploration Rovers on the Red Planet. For more information, visit www.calacademy.org/planetarium/dean.cfm.

DECEMBER 16

Holiday stroll through the Solar System

LodeStar Astronomy Center, Albuquerque, New Mexico. As part of LodeStar's Family Astro program, this event will feature hands-on activities for parents and children. For more information, call 505.841.5955; web site, www.lodestar.unm.edu/events.html.

JANUARY 7–10

American Association of Physics Teachers Winter Meeting

Washington State Convention and Trade Center, Seattle. This meeting will include many workshops, ranging from studying radio astronomy to teaching cosmology. For more information, visit www.aapt.org.

JANUARY 27

Connacht Star Party

Westwoodhouse Hotel, Galway City, Ireland. Hosted by the Galway Astronomy Club, this star party will feature prominent astronomy speakers from Ireland and the United Kingdom. Discussion topics will range from NASA missions to space science. For more information, visit www.galwayastronomyclub.ie.

FEBRUARY 10

Concert: A Universe of Dreams

Young Auditorium, Whitewater, Wisconsin. This concert will feature the music of Ensemble Galilie, narration by National Public Radio's Neal Conan, and images from the Hubble Space Telescope. Readings will include the works of Isaac Asimov. For more information, visit www.uww.edu/youngauditorium.

FEBRUARY 11–17

Cedar Key Star Party

Chiefland Astronomy Village, Cedar Key, Florida. This weeklong event offers some of the darkest skies in Florida. Attendees will host three public observing nights for local residents. For more information, visit www.upstateastro.org/stars/cedarkey.html.

FEBRUARY 12–18

Winter Star Party (WSP)

Camp Wesumkee, West Summerland Key, Florida. Sponsored by the Southern Cross Astronomical Society. The registration deadline is November 15; after this date, the WSP will charge a late fee. The 12-hour sessions at this site will provide ample time to target celestial beauties. *Astronomy* Managing Editor Dick McNally will attend. For more information, visit www.scas.org/wsp.htm.

CONTACT INFORMATION

Please submit club announcements 5 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

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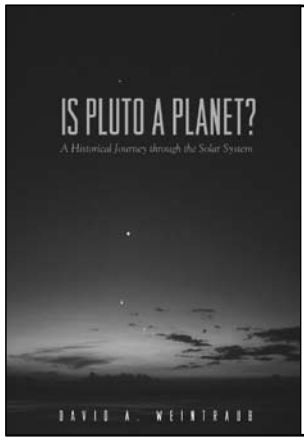

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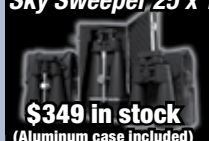

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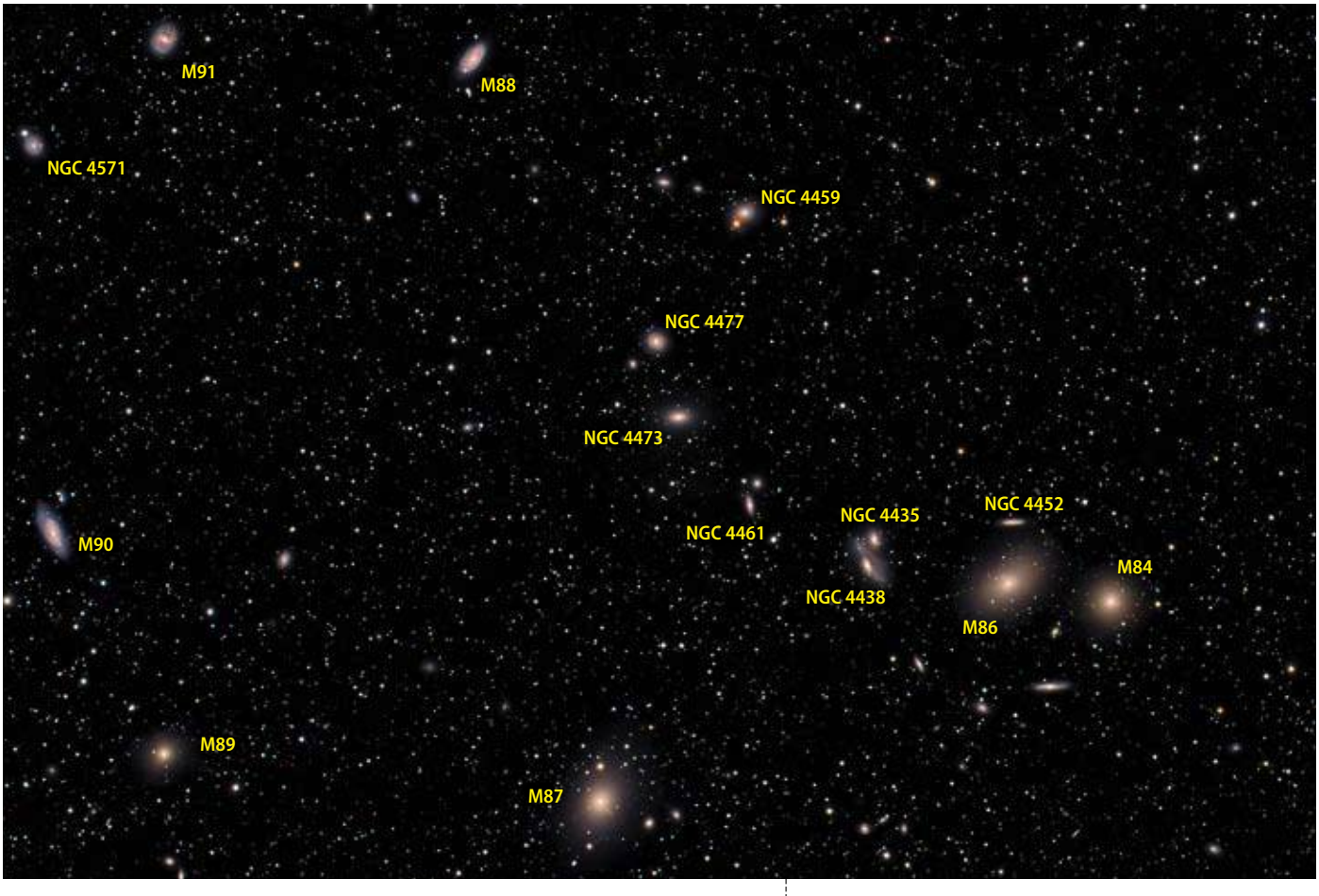

MARKARIAN'S CHAIN OF GALAXIES (4-inch Takahashi FSQ-106 apochromatic refractor at f/5, SBIG STL-11000 CCD camera, LRGB image with exposures of 100, 20, 15, and 20 minutes, respectively)
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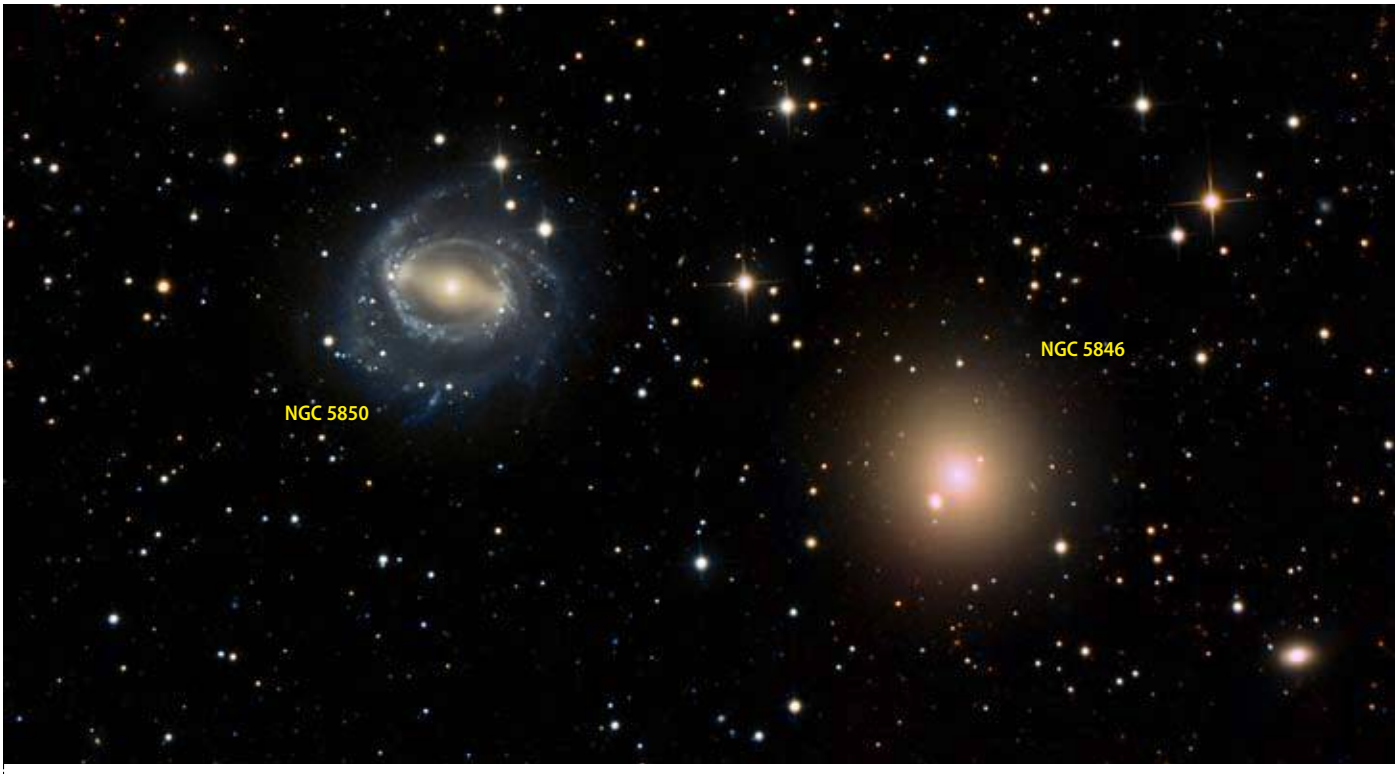
During spring, the night sky turns into a galactic festival. A parade of galaxies stretches across the northern sky starting in Ursa Major and continuing to Virgo. For observers, one of the most popular groups lies in Virgo and is known as Markarian's Chain. The curved line of galaxies, named after Armenian astronomer Benik Markarian, starts with giant elliptical galaxies M84 and M86 and ends with spiral galaxy M88. Other major galaxies in this image include elliptical galaxy M87 and spirals M90 and M91. At a dark site, an 8-inch telescope will show hundreds of galaxies in this region.



A HIGH-SPEED encounter with the massive elliptical galaxy NGC 5846 may have disrupted the beautiful barred spiral galaxy NGC 5850 in Virgo. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG STL-11000 CCD camera, LRGB image with exposures of 210, 70, 70, and 70 minutes, respectively) /// **DON GOLDMAN, ORANGEVALE, CALIFORNIA**

TWO FRAGMENTS of Comet 73P/Schwassmann-Wachmann 3 still shone brightly in early June. On the date of these images, fragments B (left) and C — stood in Pisces. (8-inch ASA astrograph at f/3.8, FLI 6303E CCD camera, 2-frame mosaic, each an LRGB image with exposures of 2, 2, 2, and 4 minutes, respectively, taken June 1, 2006, at 3h42m UT, from Farm Tivoli, Namibia) /// **GERALD RHEMANN AND MICHAEL JÄGER, VIENNA, AUSTRIA**

GLOBULAR CLUSTER M92 sometimes is called the forgotten Messier object in Hercules because of the better-known globular M13. M92 shines at magnitude 6.5 and measures 14' across. To find it, point your telescope 5° southwest of Iota (ι) Herculis. (14-inch Celestron Schmidt-Cassegrain telescope, SBIG STL-11000M CCD camera, LRGB image with exposures of 15 minutes in each channel) /// **RICHARD BEST, EAST SUSSEX, ENGLAND**

IC 4603 and IC 4604 form part of one of the sky's most colorful regions — the Rho Ophiuchus complex, located north of the bright star Antares (Alpha [α] Scorpii). The dark lane within bluish IC 4604 is Barnard 42. (5.6-inch Takahashi Epsilon 160 hyperbolic astrographic reflector at f/3.3, SBIG ST-8MXE CCD camera, LRGB image with exposures of 70, 20, 20, and 30 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**

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- Celestron's Schmidt-Cassegrain optical system with STARBRIGHT XLT Coatings. Recognized worldwide for superior optical performance.
- SkyAlign Technology: the fastest and easiest alignment in the universe. Point the CPC at three bright objects in the sky (no need to know the names of the objects) and the telescope figures out the rest.
- Internal GPS: quickly and easily establish your position anywhere on the planet for a faster and more accurate alignment.
- Flash Upgradeable: conveniently upgrade your CPC's operating software via the Internet.
- 10" Wide Ball-bearing Drive Base: to ensure image stability.
- Precision Engineered Focusing System: does not require the primary mirror to be locked during imaging like competing Schmidt-Cassegrain telescopes.

11" Celestron Professional Computerized Telescope (CPC 1100 GPS)

CPC 1100 GPS

[1] All CPC telescopes feature meticulously matched and hand-figured optical systems as well as an ergonomic design for easy transport.

[2] The CPC flash upgradeable hand control contains a database of over 40,000 celestial objects and advanced software features including SkyAlign, Periodic Error Correction, Identify Mode, User-definable Horizon Limits, and Precise GoTo.

[3] The CPC's stability and smooth tracking make it a great platform for astrophotography (an optional wedge is available) Image: M51 shot with the CPC 800 GPS.

[4] Newly designed heavy-duty steel tripod with accessory tray; center leg support bracket; spring-loaded mounting screws and recessed mounting platform for quick setup.

CPC 800 GPS XLT (8")	$1999.00
shipping and handling $95.00	
CPC 925 GPS XLT (9.25")	$2499.00
shipping and handling $115.00	
CPC 1100 GPS XLT (11")	$2799.00
shipping and handling $125.00	

Suggested retail in U.S. Dollars. Pricing and shipping charges are suggested for products ordered and shipped in the U.S.A. only.

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